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Export Effort Inadequate

CONCERNED with the number of reports reaching us expressing the view that British efforts in the Italian market were lacking in impetus *Nuclear Engineering* has undertaken a survey of Italian concerns in which senior men in all the organizations responsible for nuclear developments have been interviewed and their opinions sought on matters of vital concern to our export market. The position is not encouraging; it would appear that we are losing ground to our real competitor—the United States.

In January (page 3) we analysed the make-up of the generation industry in Italy together with the programmes then in force. This is amplified in this issue (page 139) by a summary prepared by Professor Felice Ippolito, Secretary-General of C.N.R.N. which clarifies the functions of C.N.R.N. (or C.N.E.N.) in relation to government projects and, in particular, to the ENSI project, the 150 MW(E) power station for which SENN has requested tenders to be complete by April 15. The importance of the Fiat-Montecatini group (SORIN) is, however, not brought out, for this group, quite apart from establishing an impressive research establishment built around an A.M.F. swimming-pool reactor, is proposing to construct a large power station (the type is not yet determined) and is actively investigating a process steam/electricity generation plant. The timing on the power station is uncertain and is probably dependent upon the atomic energy bill, but contracts could be placed this year. This group's own demands amount to 10% of the total power consumed in Italy. Briefly, the interest of the two component companies can be summarized as Fiat—reactor constructors, Montecatini—constructors of conventional plant. Fiat has already concluded agreements with Westinghouse of America and Montecatini is associated with Atomics International in the North American Aviation's tender to SENN. This is in spite of Montecatini having a stated preference for the gas-cooled type. The importance of these agreements cannot be overemphasized in terms of both SORIN's own projects and the SENN tender. The position can still be rectified as Montecatini would today, welcome an approach by a British consortium to act as consultants and/or suppliers of conventional equipment.

In the past few weeks (and subsequent to Professor Ippolito's article) there has been a change in the organization of AGIP Nucleare. The power station project planned to generate electricity at 6-6½ Lit./kWh (equivalent to a conventional station buying fuel at £10/ton) for which negotiations with the Nuclear Power Plant Company should be concluded on July 1, has been transferred to SIMEA which is 75% AGIP and 25% Finelettrica, AGIP taking over the previous SIMEA project for which letters of intent had been exchanged with Vitro Corporation of America and augmenting it with an alternative project for which letters of intent have been exchanged with Babcock and Wilcox of America. It is understood that the purpose of this organization is now to examine critically the pressurized water and boiling water reactors with a view to building at least one of them in the South of Italy. The transfer of the N.P.P.C. station to SIMEA simplifies any distribution problems as Finelettrica which controls supply in the south of Italy is committed to taking any surplus electricity from the SIMEA plant.

In spite of these two water projects AGIP is publicly advocating the exclusion of the other British consortia from Italy, ostensibly to avoid duplication of experience. This, of course, ignores the differences in the various British designs and takes no cognizance of the SELNI (Edison) project nor its own plans, which taken together, involve three water reactors. High politics are, no doubt, behind this move as certain factions are making strenuous bids for a near monopoly in the fuel and power sphere. It is significant that the Nuclear Power Plant Company will now, not be tendering for the ENSI station. What is certain is that outside the SIMEA project AGIP will not be exerting a pro-British influence.

The absence of an atomic energy bill in Italy has been a complicating factor in the considerable commercial manœuvring that has gone on. Not all factions are anxious for the terms to be finalized and one suspects that one of the driving forces in making agreements has been to present parliament with a fait accompli on a number of fronts. The fear of complete nationalization of both generation and supply seems to be receding but, whatever the final outcome, it would seem clear that C.N.R.N. as the official government organization must hold a central position of power and influence, if only because it will be the safety authorizing body and will be responsible for the acquisition of fuel which must come through Euratom. Certainly the recommendations of C.N.R.N. will be of great importance in the SENN project and it seems unfortunate that a point has not been made of ensuring that the Secretary-General has been shown U.K. installations as he has those in the U.S.A.

Italy is probably the most important power reactor market in the world. By 1965 the import of fossil fuels can amount to 10% of the total national import figure, for power station consumption alone; this represents a cost equivalent to £80M. Natural gas supplies are being developed and hydro potential is not quite fully exploited, but the annual increase in demand shows no sign of slackening and a comprehensive building programme of nuclear power stations is a prime necessity. The U.K. with its proud home record should be in an unassailable position as supply country but apart from the SIMEA project, we have no other hold in Italy and the position will steadily deteriorate unless more positive action is taken.

The only reactors (research) actually under construction in Italy are American. The SELNI PWR station similar to the Rowe plant is likely to begin construction within weeks of the SIMEA station and all the time American prestige and American influence is on the increase. Furthermore, Italy is not short of dollars, showing a net surplus in 1957 of $285m. The existence of the SELNI PWR project is another direct result of British apathy. Edison came to

England in September, 1956, to investigate the Calder type but left, feeling that we were not greatly interested in a project not related to the U.K. generation programme. With the C.E.A. tenders about to go in, this was a busy time, but this was a great opportunity lost. A contributing cause was also the advantageous terms offered by the Export-Import Bank but financing overseas ventures was once not an American monopoly.

Prestige

British prestige in Italy in the field of nuclear engineering is significantly less than our due. With the material available, the official information services appear to do all that is possible but their hands are tied when it comes to advertising and in Italy it is difficult to get proper editorial coverage without advertisements to back it up. Publicity by the consortia is sporadic, and only loosely related to local conditions. There is also insufficient appreciation of the influence that politics and prestige have on what theoretically are purely technical matters. The U.K. (unlike France) will not be showing developments in the nuclear energy field at the Milan Fair (April 12-27) in spite of the B.o.T. offering financial assistance. This Fair, spanning the date for the receipt of the SENN tenders, occurs at a time when interest in the subject will be at its highest. Similarly no plans exist for U.K. participation in the Fifth International Electronic and Nuclear Energy Exposition and Congress, in Rome, June 16-30. Needless to say, in both Rome and Milan the U.S.A. will be present in strength.

Personal Contact

It seems extraordinary that Italy—only 2½ hours away by Viscount—should seem closer to the U.S.A. than to the U.K., but in general, senior staff would appear to be more familiar with U.S. installations and personnel than with those in the U.K. Certainly the U.S. appears to be more closely linked with Italian enterprises and to be more surely in touch with developments there than the U.K. It is understood that the appointment of a British consulting concern—Kennedy and Donkin—to SENN was not made until more than 3 months after instructions had been given to America's Internuclear Company. Even now U.K. representation is outnumbered seven to two and the A.E.A. has no permanent consultants established in Italy to watch the whole market. In fairness, it must be stated that the A.E.A. has given valuable assistance to a number of organizations, notably SORIN, but it points the fact that the Authority does not identify itself with commercial interests when its advice on the research establishment should be associated with an American reactor.

European Co-operation

We are now beginning to reap the results of our insular and short-sighted attitude towards Europe over Euratom and O.E.E.C. This has caused the gravest resentment and distrust whilst the U.S.A. is looked upon as an outside benevolent power. In February we expressed surprise at the Eurochemic project, but at that time were ignorant of the fact that the U.K. had partially withdrawn from the enterprise and as a result it was decided to go ahead with a pilot plant with France as main consultant, and no doubt French industry as main suppliers. It is quite likely that this lukewarm attitude on our part will cost the United Kingdom chemical engineering industry millions of pounds in exports, as it is the intention to build, over the years, a great number of medium-scale fuel processing plants throughout Europe. After this beginning it is highly unlikely that we can re-enter the market unless the Government is prepared to make a vigorous change in attitude.

International Agreements

At the time of writing it seems impossible for the Italian Parliament to approve the bilateral agreement with Britain before the elections and it will not be dealt with until June or July. We do not believe that this will materially affect either the SIMEA or the SENN projects, but it is a further complicating issue and further evidence of our lack of thrust. There is no real reason why this agreement could not have been concluded many months ago and no possible excuse for the U.S. agreement to have gone through while ours hangs fire. Each delay is another set-back and represents another lost skirmish in the export battle.

Position at Home

Returning to our promotional problem in Italy, this is in part explained by the peculiar relationship between the consortia and the U.K.A.E.A. and the dominant position of the latter whilst the company association N.E.T.A.C. has only limited strength and consequence. The exclusive concentration on the home market of two years ago was short-sighted, if understandable, as developments have been more rapid than anticipated; but the results of this exclusion are with us now. In addition, it was not expected that individual reactor outputs would increase so rapidly and that, therefore, the number of stations being built at any time in this country would be so small; G.E.C., for example, this month suggests 400 MW (E) per reactor as a probable economic figure in the near future. The necessity for establishing an export trade is thus suddenly more acute, but so keen is the competition between the consortia that the real competitor in the outside world—America—tends to be neglected. In addition, the cost of preparing even sample tenders is high and the time involved long, so it is vital that there is a real chance of an ultimate sale before the work is begun. The U.K.A.E.A. on the other hand can represent all groups and speak with real authority. Being a government organization, however, it has not yet built up the necessary machinery to take its responsibilities to their logical conclusion.

We repeat that we are not taking the opportunities open to us in Italy and the same will happen elsewhere. We submit the following proposals for consideration.

1. The U.K.A.E.A. should set up its own Sales Office

The responsibilities of the A.E.A. must be re-defined to fill the present vacuum. The A.E.A. has set itself up as an industrial concern, selling graphite and fuel and levying royalties on designs. Of such value is the fuel that total capital cost of any station is less than the overall fuel cost and for an overseas contract, where a considerable proportion of the constructional effort will be supplied by the purchasing country, as much as 75% of the income to this country will be to the U.K.A.E.A. It is quite wrong, therefore, that industry should be expected to carry all the cost of sales and it is the duty of the A.E.A. to bear the brunt. In addition, by selling natural uranium, it can forcibly sell for all the groups. The influence of Sir Christopher Hinton's visit to Japan is clear-cut evidence of the power that the U.K.A.E.A. could wield.

2. The Sales Organization should be on Commercial Lines

The sales organization should be set up on the lines of other commercial undertakings with proper financial appropriations for promotional work. The sums allocated would, of course, be dependent upon the potential market; the present rigid system whereby the Treasury authorizes expenditure quite unrelated to expected income is manifestly illogical. This is a business venture and must be run on business lines.

3. Resident Agents Abroad should be Appointed

The sales director would, of course, be a person of consequence with a good technical background but experienced in large-scale overseas contract work and he would be supported by a sales staff with offices and agents all over the world. It is imperative that men familiar with the local conditions be employed either as resident agents or consultants and these men should also be persons of standing who can gain the respect of the native technical and commercial leaders.

4. The Consortia Should Appoint Licensees

To a large extent the original naive approach of selling only complete power stations has died, but it is apparent that the absolute necessity of taking native companies into partnership is still only partially appreciated. Italy and the SENN project is an outstanding example of the failure of the consortia to concede fully this point, and the extent of Italian participation could well be the deciding factor in determining where the contract shall be placed. Yasukawa made it quite clear to *Nuclear Engineering* during his recent visit to the U.K., that cost per kWh is of secondary importance to the proportion of local constructional effort included in the Japan tenders.

5. Co-operation with Europe should be Fostered

Even when Commonwealth loyalties prevent our sharing as much as we should in European developments, this country must do all in its power to ensure that our friendship with Europe is undamaged and that our position is fully understood. There must be no more backing down on co-operative undertakings on any grounds. Europe will not come to us if we are unwilling to go to it. If the Government is anxious to increase exports it must not at the same time deliberately create barriers but, instead, go all out to remove them.

6. A Finance Fund should be Established

High capital cost is a major obstacle in selling nuclear power stations. There is no reason why capital should not be raised either by the Government or the City to finance overseas projects. Interest rates are lower in general in this country than elsewhere and it is not true to suggest that the money could not be raised by private investment. We should be greatly surprised if there were not an immediate and overwhelming response by private investors if the opportunity were afforded them. It is, perhaps, surprising that the City on its own account has made no move in this direction.

7. These Matters should be treated as URGENT

Having established an acknowledged lead in nuclear power station developments it is tragic that we should lose this opportunity of re-establishing ourselves as the leading engineering export country. Technical excellence alone is not enough; power stations, like aeroplanes, must be *sold*.

The Nuclear Programme in Italy

OWING to the lack of a law regulating the peaceful uses of atomic energy in Italy, the position of the "National Committee for Nuclear Research" (C.N.R.N.) was not clearly established until November 29, 1957, when the Council of Ministers approved a law to be examined by the Chambers as soon as possible; the approval of this law means that a big step forward has been taken towards the promotion of a nuclear energy programme in Italy.

Said law changes C.N.R.N. into a National Council for Nuclear Energy, headed by the Ministry of Industry. The Council has the right of undertaking studies and research in the atomic energy field, of taking care of the production of special nuclear materials and will also deal with the storing of source-materials.

The "Consiglio Nazionale per l'Energia Nucleare" (C.N.E.N.) has been granted the authority to control, on behalf of the Government, all atomic establishments to be built in Italy. C.N.E.N. will also provide for the training of specialized technical personnel and co-operate with foreign agencies and international organizations.

Another point of maximum interest is the budget allotment of 50,000 million lire in respect of the next five years. Thus financed, C.N.E.N. will be in a position to perform the 5-year programme, now being elaborated by C.N.R.N.

Our Committee's main achievement up to date is the erection of the Frascati National Synchrotron Laboratory. The National Synchrotron Laboratory has been built to take in the 1,000 MeV electron synchrotron which the National Institute for Nuclear Physics had decided to construct four years ago. The machine is already being completed, as the magnet has now been received from Ansaldo S. Giorgio Co.

The construction of the National Centre for Nuclear Research at Ispra, near Varese, has been the other major work and was started two years ago (1956); it is expected to reach completion in 1959. The first Italian research reactor will be the Ispra-1, a CP-5 type reactor, entrusted to ACF Ind.

It is well established that, in regard to the economical competition between conventional and nuclear power, Italy finds itself in a rather favourable situation towards the latter source of energy.

This is due to high cost of fossil fuel, fully utilized hydro energy and increasing power demand with particular preference to industrialization plans in the economically depressed areas of the South of Italy.

Four Nuclear Utilities groups have set themselves a goal of operating within the next five years four nuclear power plants for an output of roughly 630,000 kW(E), distributed as follows:

Company*	Envisaged Reactor Type	MW(E)
AGIP NUCLEARE:	Gas-cooled reactor	200
SELNI:	Enriched U pressurized water	140
SENN:	To be decided after bid	150
SIMEA:	Enriched U pressurized water	140

* In addition a fifth nuclear firm is considering building a gas-cooled reactor of 200 MW(E) and an enriched U water-cooled system of 140 MW(E).

Some of these companies have already signed consultantship contracts and letters of intent abroad while they are actively carrying out their programmes for staff training and research installation. It is interesting to note that the four reactors will be generating, by 1964, 6% of the national electrical output.

One project which deserves particular attention is ENSI.

This project is a co-operative study sponsored by the Government of Italy and the World Bank for the purpose of selecting plant type and supplier for a 150(±10) MW(E) nuclear power station in Southern Italy (mouth of the Gargliano River) to be contracted for by SENN (Società Elettronucleare Nazionale). It has developed from a comprehensive study on the economical applications of nuclear energy performed by Mr. Corbin Allardice, adviser on Atomic Energy to the World Bank.

Project ENSI is composed of:—

(1) A "Steering Committee" responsible for overall direction, composed of the Secretary-General of C.N.R.N., Prof. Felice Ippolito, and the Adviser on Atomic Energy to the World Bank, Mr. Corbin Allardice.

(2) A "Working Group" formed by SENN's staff, members of Italian Utilities, of C.N.R.N. Power Reactor Department

and of American and British Consultants: Internuclear Co. of Saint Jonis and Kennedy and Donkin.

The work of ENSI includes:—

(a) The selection of a plant site.

(b) The preparation of an invitation to tender to qualified manufacturers.

(c) A review of the tenders submitted and the preparation of technical reports on them, particularly regarding cost and performance.

The U.K. Atomic Energy Authority and the U.S. Atomic Energy Commission have agreed to provide nuclear engineering consultants to the project, while the World Bank has established an International Panel of highly recognized specialists in the field of Nuclear Energy to give general guidance and to review tenders and the reports on them provided by U.K.A.E.A., U.S.A.E.C. and the Working Group.

The work is already progressing as scheduled:—

(1) Plant site survey is nearly completed with foundations pile testing under way at the mouth of the Gargliano River.

(2) The Working Group under the direction of SENN's President, Prof. Carlo Matteini, assisted by C.N.R.N.'s Head of Power Reactor Dept., Ing. Aldo Forcella, is actively engaged on the second stage of its work, namely, preparation of evaluation standards, analysis of technical and economical features of gas-cooled reactors and enriched uranium water-cooled systems.

The third stage of the work will start on April 15 when bids will be evaluated and will last until the end of the year. SENN will then select the most suitable tender for the construction of the nuclear power station having available the investigations provided through Project ENSI.

Through the work of ENSI Organization, the C.N.R.N. and the World Bank hope to solve the delicate problem of choosing the most favourable type of reactor system among those presently available in the market and for the existing condition in the network.

FELICE IPPOLITO,
General Secretary of C.N.R.N.

Commentary

The Advanced Gas-cooled Reactor

In his James Forrest Lecture, Sir John Cockcroft released details of the AGR project—the Advanced Gas-cooled Reactor which the U.K.A.E.A. has been studying for some time. The objective of the AGR is to reduce overall dimensions and capital cost of reactors (it is suggested by 30%) by increasing the surface temperature of the fuel elements to about 600°C. In addition, smaller diameter fuel elements would be used in clusters to allow a thermal rating of 8 MW/ton. Ceramic fuel elements, probably clad in beryllium, will be used in the reactor, experimental work having shown that elements sheathed in beryllium and thermocycled through the alpha/beta phase change have suffered no damage after hundreds of cycles. Loop work in DIDO is continuing while NERO has been employed to study the physics of the reactor.

It is anticipated that capital costs of the order of £80/kW installed capacity could be achieved with this type of reactor in the late 1960s. The design changes mentioned will, of course, decrease the neutron economy and some enrichment will be necessary. A probable figure is 30% increase in U^{235} content over natural uranium, i.e., 0.9% U^{235} in U^{238}.

The site for this project has not been finally determined but it is almost certain that the Windscale establishment will be chosen. There is adequate space at this site for such an experiment as well as having a design and construction staff already in residence and services available. The programme will be handled by the Industrial Group and it is possible that work will begin on construction towards the end of the year. A great deal of effort is being expended on establishing the technology of beryllium. There are still bodies of opinion who feel that the problems of fabrication cannot be surmounted economically but, on the whole, there is growing confidence in beryllium as a canning material.

The results of the AGR experiment will be awaited with considerable interest, not only by power station authorities but also by the shipping industry, although the gas-cooled heavy-water moderated reactor would seem to offer equal economies with probably easier technologies. The other aspect of the heavy water reactor that could be of considerable significance concerns its ability to burn plutonium. If the moderator remains cool even under fault conditions, and the temperature of the neutrons can be considered equal to the moderator temperature, the unpleasant energy/cross section characteristics of plutonium should not create an overall positive temperature coefficient even with a pure (dilute) plutonium core. The programme for the fast reactor is being steadily put back and although supplies of plutonium will not be significant for another seven or eight years, a reactor system which is capable of burning this material can have important economic advantages.

It was surprising that in his lecture, Sir John omitted to mention the organic moderated reactor. The potentialities of this system seem considerable and although it is recognized that the effort available in this country is limited, the promising results on OMRE would indicate that greater attention should be paid to this system than would appear to be the case.

European Insurance Agreement

The second International Atomic Energy Insurance Conference came to an end on February 28. Fifteen European countries were represented and agreement was reached on all the essential matters discussed. These concerned the probable extent of third party liability and the premiums that would be charged.

Although figures were not quoted at the conference it is believed that at least initially, a premium rate of 0.75% of the sum assured will be adopted. This is three times the premium charged for third party aircraft risks and would seem to be excessively high. A simple calculation on this basis would indicate that a major reactor incident involving the maximum risk can be expected approximately once every hundred years for each reactor installed. By 1962 there will be at least twenty-four power reactors in this country alone and therefore a catastrophe must be expected once every four years. This is clearly not a true picture of the probabilities as we could not conceivably afford to plan a programme which involved major accidents at this sort of frequency.

Considerable expense is, of course, incurred in setting up the machinery to organize insurance coverage and insurance companies understandably wish to amply cover their possible outlay. It would seem that this will be achieved with a generous sum in hand, but at the same time it must be emphasized that the effect on the cost per kWh is negligible. A more serious aspect is the load this places on the operators of research reactors. It is generally agreed that reactor owners rather than constructors shall be totally responsible for third party risks and it is to be hoped that the sum assured can be kept to a reasonably low figure. This has its dangers for the owner of course, should a catastrophe involve him in claims over and above the sum that has been guaranteed.

It is hoped that the terms discussed will be reduced as soon as possible in the light of operating experience and will not, as with the excess personal occupational premiums, remain in force long after they had been shown to be unnecessary.

PLUTO—Measurement and Control—1.

BASIC DESIGN PHILOSOPHY

By J. WALKER, M.A., A.M.I.E.E. and
F. E. LIDDIARD, A.M.I.E.E.

Basic principles and scope of the instrumentation which a research reactor requires are considered in this article.

THE starting point of any consideration in the design of an instrumentation system for any reactor is safety. Instruments must be numerically adequate and sufficiently reliable to provide the operator with all the information he needs for the safe conduct of the plants associated with the reactor as well as of the reactor itself.

The second point which has to receive careful study is usefulness of the reactor as a research tool. It should be emphasized that the prime object of this reactor is to make regions of high neutron flux available for experimental purposes. Thus, not only must the instrumentation be adequate to meet safety requirements, but it must also be sufficiently generous and flexible to permit a full and uninterrupted use to be made of the reactor by experimentalists. (Some indication on the method of interconnection between the main instrumentation of the reactor and the experimental "loops" is given in Fig. 3 and described under "Safety Circuits.")

A reactor of this type, e.g., DIDO, PLUTO, DMTR or HIFAR, with its essentially expensive construction materials (enriched uranium, heavy water, special steels, helium, etc., and highly specialized auxiliary equipment such as purification units and water-treatment plant) represents a large capital investment in which outage time costs money. Every effort must, therefore, be made to ensure that any outage, including that for fuel recharge, is kept to an absolute minimum. Since the high flux brings with it the troubles associated with xenon poison-out, the safety circuits must be kept as free as possible from spurious action, which, while not unsafe, can have a significantly adverse effect on the overall operating economy.

Control Location

Arising jointly from the question of reactor containment and of maximum usefulness of the reactor space, a very important decision which has to be made is of location of the nerve centre of the reactor instrumentation—the control room. The reactor is within an airtight containment vessel, and a real premium is placed on experimental space. It may be argued that this space should not be used to house the reactor control room, but that an external control room should be built. This argument is strengthened by the space limitations which will be placed on the instrumentation by including the control room within the reactor shell. On the other hand, the operational management of the reactor must be considered, and ease of communication between operations and experimental staff is of vital importance in a plant where several experiments may be disturbed by malfunctions on any one. Further, in this reactor, the experiments are chiefly of a complex engineering nature and, because of the heating and radiation problems associated with high-flux operation, are usually heavily shielded and unobserved. Quick access to these experiments is very important. On these considerations the control room has been included within the valuable "in-shell" space, as was also the case in DIDO. For reasons which will be dealt with later the amount of instrumentation is greater in PLUTO than in DIDO, and the desirability of miniaturized instruments is emphasized. It is felt that there is considerable scope for further developments in this field.

As with DIDO, a secondary control room is provided external to the reactor shell. It is known as the "Emergency Control Room," but a better description of its function is given by "Incident Control Centre," since its use is not to provide a second and possibly conflicting point from which the reactor can be controlled, but rather to provide a focal point for damage control in the very improbable event of a reactor incident in which damage had occurred to the reactor structure. This incident control centre is adequately protected to enable control to proceed. It contains no reactor control or safety mechanism actuators other than a single shut-down push-button and reset key, but is a remote handling point for several important valves in the various fluid circuits of the reactor and of the building ventilating air.

Bestriding the general requirements discussed above, all of which point to more and more instrumentation, is the general requirement for economy, and there are no doubt points in the instrumentation philosophy where the "necessary" and "sufficient" technical requirements are all that have been met, and some items which might be classed as "convenient" have been omitted on cost grounds.

Scope of Instrumentation

In order to appreciate the complexity of the installation it is useful to consider for a moment the various items on the reactor requiring instrumentation. From this it will be seen that, important though it is, the conventional nucleonic instruments represent only a portion of the total. First of all then, let us look at the fluid circuits of the reactor. They are:—

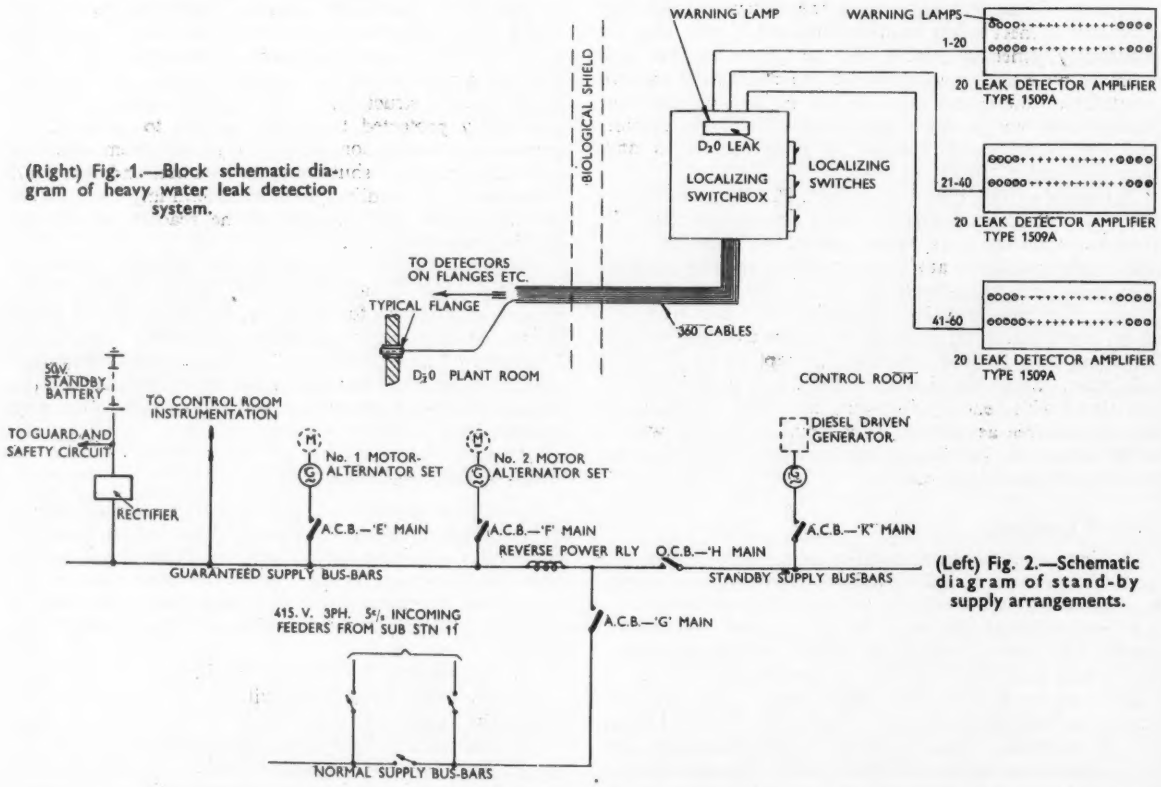
1. The primary heavy-water circuit.
2. The primary helium circuit.
3. The reflector helium circuit.
4. The primary light-water cooling circuit.
5. The shield cooling water circuit.
6. The experimental cooling water circuit.
7. The fine control-rod cooling water circuit.
8. The carbon dioxide purge circuits.
9. The demineralized water-treatment plant.
10. The reactor shell ventilation system.
11. The fuel unload flask cooling circuit.

On the back of the pull-out, facing page 151, is the Reactor Mimic Diagram which is displayed in the Control Room and indicates the position of a number of the most important industrial control instruments associated with fluid circuits. These instruments are required to be of a "fail to safety" nature. To meet this requirement a careful

choice of instruments has to be made necessitating the development of new types and, in some cases, special modifications to standard commercial items.

The provision of the Dump Valve is of particular interest as it forms a separate circuit by itself. A "Dump" of heavy water from the Reactor Tank is provided under the direct control of the Reactor Operator via a special emergency button. The action of dumping removes the top 24 inches of heavy water reflector from the reactor tank and so reduces reactivity (5.6% $\delta K/K_{eff}$). It is not automatically invoked for all shut-down fault conditions, since under certain combinations of reactor tank or primary coolant circuit fracture this reduction in primary coolant volume could result in overheating of the fuel. Unlike other methods used to reduce reactivity, dumping would only be used exceptionally, and after careful consideration had been given to its effect on the coolant circuits.

The heavy-water leak detector monitoring system is also one of considerable interest. Not only is heavy water very expensive, but it is vital to the operation and safety of the reactor that the correct working levels should be maintained. When irradiated it becomes active, so it is important that any leak of heavy water, however small, should be quickly detected. Valves, flanges, pumps and joints in the heavy-water circuit, where mechanical failure could cause leakage, are monitored by means of special conductivity detectors. The detectors are cabled separately back to the localizing switchbox located in the control room where they are paralleled in groups of six and are connected to 60 leak detector amplifiers. Thus a total of 360 detectors can be installed and individual selection at the switchbox enables any leak to be located very quickly from outside the heavy-water plant room. Fig. 1 gives a block schematic of this system.



(Right) Fig. 1.—Block schematic diagram of heavy water leak detection system.

(Left) Fig. 2.—Schematic diagram of stand-by supply arrangements.

In addition to the above, there is extensive plant for providing a guaranteed power supply, for shut-down fission product heat removal and reactor control, under mains supply failure conditions. Fig. 2 gives a schematic diagram of the guaranteed supply system.

The nucleonic instrumentation of the reactor is considerably more involved than on previous reactors built in this country, including as it does not only the reactor flux and period measurement, and the normal quota of health physics instrumentation of the various reactor working spaces, but a number of new items which are peculiar to the type of reactor. Among these must be listed:—

(1) Fission product monitoring equipment, DIDO and PLUTO representing our first experience of this problem in water-cooled systems.

(2) Provision of adequate flux scanning equipment. This is of considerable importance in a reactor where marked asymmetry of flux distribution can occur, as the effective reactor geometry changes, with control absorber position, during the build-up of fission product poison.

(3) The inclusion, as a permanent piece of installed instrumentation, of an analogue computer, providing continuous information on the state of reactor xenon concentration, with the facility for prediction of its mode of decay in the event of reactor shut-down.

Control Mechanism Instrumentation

In the interests of space economy, the position of the seven coarse control arms, which are all driven from one single master drive unit, is given by indicating the position of the master unit only. In order that reliance can be placed on such an indication, "misalignment" detection units have been developed, giving warning of discrepancies of rod position from that of the master drive unit. In

retrospect, the saving achieved by this design philosophy appears to be marginal, and should not be regarded as a standard practice for this type of reactor.

Reactor Safety Circuits

The guard and safety circuits are designed to operate on a "fail to safety" basis. Circuits are arranged so that relays are released and contacts are opened to give the warning or trip conditions. In this way, relay failures, and the vast majority of circuit faults which could possibly occur, produce a safe circuit condition similar to that provided by a reactor warning or trip; standard P.O. 3000-type relays are employed wherever possible as being very efficient and reliable. The relays are mounted in jack-in relay sets and a full complement of spare sets is provided. A working set can thus be quickly replaced and the reactor outage time reduced to a minimum. The relays are operated from a 50 V d.c. supply, derived from a rectifier unit fed from "guaranteed" mains. A small-capacity secondary storage battery is floated across the 50 V d.c. supply and serves to mask any voltage fluctuations which might occur on failure of normal supply and consequent change-over to guaranteed mains (Fig. 2).

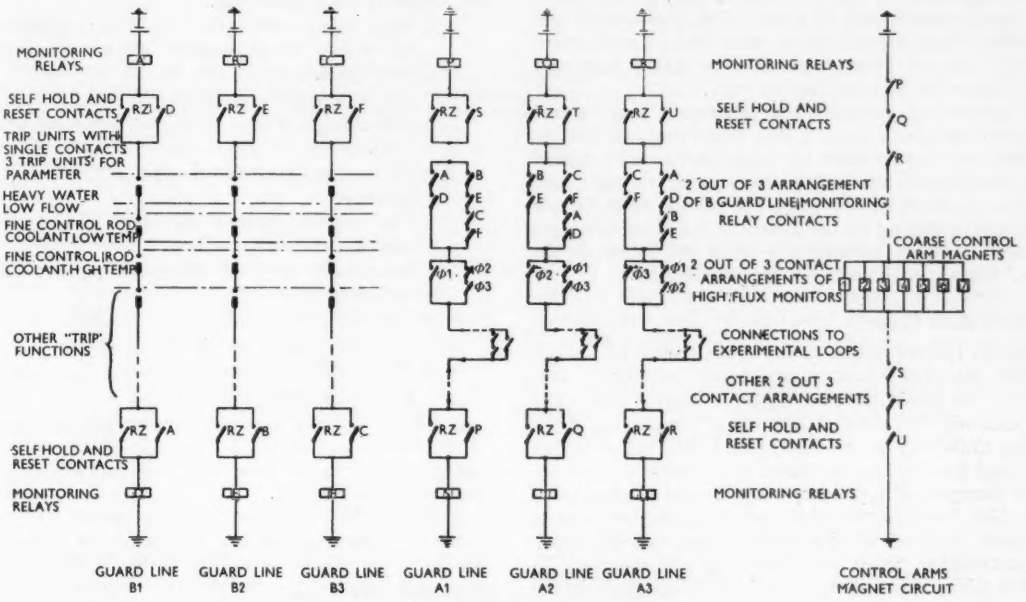

MONITORING RELAYS
SELF HOLD AND RESET CONTACTS
TRIP UNITS WITH SINGLE CONTACTS 3 TRIP UNITS FOR PARAMETER
HEAVY WATER LOW FLOW
FINE CONTROL ROD COOLANT LOW TEMP
FINE CONTROL ROD COOLANT HIGH TEMP
OTHER "TRIP" FUNCTIONS
SELF HOLD AND RESET CONTACTS
MONITORING RELAYS
MONITORING RELAYS
SELF HOLD AND RESET CONTACTS
2 OUT OF 3 ARRANGEMENT OF B GUARD LINE MONITORING RELAY CONTACTS
COARSE CONTROL ARM MAGNETS
2 OUT OF 3 CONTACT ARRANGEMENTS OF HIGH FLUX MONITORS
CONNECTIONS TO EXPERIMENTAL LOOPS
OTHER 2 OUT 3 CONTACT ARRANGEMENTS
SELF HOLD AND RESET CONTACTS
MONITORING RELAYS
GUARD LINE B1
GUARD LINE B2
GUARD LINE B3
GUARD LINE A1
GUARD LINE A2
GUARD LINE A3
CONTROL ARMS MAGNET CIRCUIT

Fig. 3.—Basic restricted-trip guard lines.

Safety Circuits

The various trip functions have been classified rather arbitrarily, until operating experience is obtained, by the type of corrective action which is taken. Over and above the normal audible and visible warning for minor fault conditions, the reactor has three degrees of trip action. These are "control reversal," "restricted trip" and "complete trip."

The "control reversal" condition is equivalent to the "power set-back" condition coming into favour in the U.S., and consists of an insertion of the primary shut-off control rods at their normal operating speed, i.e., −1% in reactivity per minute (designed). This relatively slow rate of application of corrective negative reactivity allows the operator to use judgment on measures which might make an immediate restart of the reactor possible, and reduces the rate of initial build-up of shut-down xenon poison. As installed, this set-back is unlimited; i.e., the control reversal continues until the rods are fully inserted, unless the operator takes specific overriding action. However, it is hoped to instal, shortly, an automatic control system which will have the feature of providing power cut-back to a nominal predetermined level.

The "restricted trip" consists of a gravity release of the primary control arms, which enter the reactor in rather less than 1 sec. The withdrawal mechanisms are automatically wound into the reactor after the fallen arms, at five times the normal maximum rate. As before, the object of increased speed is to complete the reconnection of arms as quickly as possible in order to win the inevitable race against xenon poison if a restart is required immediately. The normal withdrawal or insertion time for full rod travel is 25 minutes.

"Complete trip" is invoked for fault conditions which are felt to represent a reactor "incident" as a result of which evacuation of the building might be desirable, with further control of the incident from the Emergency Control Room. Under such a trip, the secondary safety rods are released in addition to the primary coarse control arms, and the reactor building ventilation seals are closed, to complete the reactor containment.

Fault information has been monitored in triplicate, 2 out of 3 coincidence being required before trip action is initiated. This, of course, requires three devices to detect each individual fault condition. The same philosophy has been applied to the guard circuits themselves, so that faults within the circuitry shall not lead to unnecessary shut-downs.

In some cases, where simple, single-contact sensing devices have been used, a special safety circuit (B guard) permits the information obtained to be fed to all three of the main safety circuits (A guard).

Fig. 3 shows the basic design as applied to the "restricted trip" condition and is typical. The A guard lines are monitored by relays P, Q, R. S, T and U, whose contacts are series arranged to release control arm magnets. The lines contain cyclic arrangements of contacts from trip

sensing devices (e.g. Φ1, Φ2, Φ3 in Fig. 3) where it has been possible to provide a large number of contacts on each device. They also contain cyclic arrangements of contacts on the monitoring relays of the B guard lines A, B, C, D, E and F.

This system will allow any individual monitoring or trip unit to be removed from circuit for maintenance or check purpose, without resulting in a reactor trip. Under these conditions a warning will be given. The provision of two monitoring relays placed one at each end of each guard safeguards against earth faults on the guard lines and possible failure of one monitoring relay.

The method of connecting experimental loop instruments into the guard lines is also illustrated. It will be noted that provision is made for fault conditions on experimental equipment to control the reactor in the same manner as the fault conditions on the reactor itself. Details of connections depend on the nature of the experiment and the extent to which failures will affect the safety of the reactor. Each case is treated on its own merits.

Shut-down State Guard

When the reactor is shut-down in the course of normal operation, the coarse control arms and fine control rods will be in the full-in position, as for a reactor trip. The safety rods will be raised, and be under the control of the complete shut-down guard lines, which release for higher trip settings for flux, temperature, etc. Should the reactor become divergent with primary control arms inserted (very improbable), it will be necessary that the safety rods should be dropped before these high settings were reached, otherwise the resultant power overshoot might be serious. To cater for this a "shut-down state" guard circuit is incorporated which comes into operation at normal shut-down, after the insertion of the control arms and the decay of neutron flux below a nominal low level. Under this condition the release of the safety rods is under the control of flux trip with a very low setting, and of the reactor period meter trips.

Operational Sequence Interlocks

The guard and safety circuits include a number of complex electrical interlocks which prevent any potentially dangerous or undesirable sequence of operations from being initiated.

For example the coarse control arms can be raised from their full-in position and the reactor made critical only if the following conditions exist:

(i) Both safety rods are "up," in a position from which they can be dropped into the core should the need arise.
(ii) The dump valve is closed.
(iii) The reactor tank is filled to the correct level with D_2O.
(iv) The correct number of main D_2O circulators are running.
(v) The correct number of main H_2O pumps are running.
(vi) No control reversal, restricted trip or shut-down condition exists.
(vii) The fine control rod has been raised.
(viii) The fine control rod is not in motion.
(ix) The multi-range power indicator is operating and a signal is being received.

It will be seen that considerable thought has been given to providing in this plant a safety system with a high integrity which at the same time produces as few spurious shut-downs as possible.

A high incidence of spurious shut-downs has not only economic consequences, but can prejudice operator confidence in the reactor protection system. As is shown, the dual and conflicting requirements of safety and serviceability do lead to complications in the safety design philosophy. While every attempt must be made to render the safety as fool-proof as possible, it must be appreciated that this in no way relieves us of the necessity for a proper administrative control of a plant whose usefulness can depend to a large measure on its flexibility.

La Philosophie de l'Instrumentation de Pluto

La sécurité est la considération de base en tout ce qui a trait à la conception des réacteurs et l'instrumentation doit être spécifiée avec ce but à l'esprit. Un réacteur de ce type représente de très grandes dépenses de capitaux, et en ce qui a trait à son utilisation "le temps c'est de l'argent," de sorte que la sécurité et l'exemption des arrêts qui ne sont pas nécessaire sont d'une importance primordiale. Il existe une différence d'opinion en ce qui concerne le caractère désirable du placement du tableau de commande dans l'enceinte de fonctionnement même, mais en ce qui concerne Pluto, l'emploi d'espace précieux a été considéré comme venant en second lieu après les avantages d'une communication rapide.

Le champ d'action de l'instrumentation y est examiné, en tenant compte du fait que les instruments nucléaires, tout en étant considérablement plus compliquésque ceux des réacteurs précédents construits en Grande-Bretagne, sont d'un volume réduit par comparaison à ceux qui se trouvent sur les circuits fluides du réacteur. On y décrit aussi les circuits de sécurité, les circuits de protection et l'enchaînement des circuits expérimentaux avec ceux du réacteur lui-même.

Die grundsätzlichen Ideen bei der Ausrüstung des Werks Pluto mit Instrumenten

Sicherheit ist der erste Grundsatz in allen Reaktor Konstruktionen, und die Ausrüstung mit Instrumenten muss mit diesem Ziel im Auge vorgesehen werden. Ein Reaktor dieser Art bedeutet eine sehr grosse Kapitalsanlage, wobei die Zeit, die ein Reaktor ausser Betrieb ist, Geld kostet, sodass Sicherheit und Schutz gegen unnötige Ausserbetriebssetzungen von überragender Bedeutung sind. Es gibt verschiedene auseinandergehende Meinungen über die Zweckmässigkeit der Einrichtung der Kontrollstellen in der inneren Betriebsanlage, jedoch war man im Falle Pluto der Ansicht, dass die Wegnahme wertvollen Betriebsraums erst an zweiter Stelle käme gegenüber den Vorteilen rascher Verständigung und Uebermittlung von Nachrichten.

Der Zweck der Versorgung mit Instrumenten wird dargelegt, wobei bedacht werden muss, dass die Anlage, obwohl sie erheblich verfeinert ist, im Vergleich mit den Anlagen, die in den früher hier im Lande gebauten Reaktoren zu finden sind, doch im Umfang klein erscheint, verglichen mit den Anlagen in den Flüssigkeits-Umläufen des Reaktors. Sicherheits-Umläufe, Schutz-Umläufe und die Zwischenverbindungen von Umläufen für Forschungszwecke mit denen des Reaktors selbst werden dann ferner beschrieben.

Filosofia para Instrumentar a Pluto

La consideración básica en el diseño de todo reactor es la seguridad y su instrumentación ha de ser especificada teniendo presente ese objetivo. Un reactor de este tipo significa un gran desembolso de capital en el cual todo tiempo perdido significa pérdida de dinero y, por consiguiente, la seguridad y la inmunidad contra suspensiones innecesarias de trabajo son de primordial importancia.

Hay diferencias de opinión en cuanto a la conveniencia de situar el tablero de mandos dentro del recinto de operaciones, pero en el caso concreto de Pluto el empleo de espacio valioso se tuvo muy en cuenta decidiéndose que era de importancia secundaria a las ventajas que ofrecen una rápida comunicación.

Se estudió lo relativo a instrumentos teniendo en cuenta que, los instrumentos nucleares, considerados más complicados que en reactores anteriores construidos en este país, significan un pequeño volumen si se comparan con los utilizados en los circuitos fluidos del reactor. Los circuitos de seguridad, circuitos de protección y el enclavamiento de circuitos experimentales con los del reactor mismo, también se describen.

PLUTO—Measurement and Control—2

NUCLEAR INSTRUMENTATION

By W. E. THOMPSON, B.Eng., A.M.I.E.E.
(*Ekco Electronics, Ltd.*)

This article outlines the nuclear instrumentation of PLUTO and describes the apparatus and the modus operandi of the monitors necessary for safety protection and health precautions, also the telemetering equipment used for control rod position indication. The principles of the "2 out of 3" system employed to ensure absolute safety in operation without false tripping are briefly recapitulated.

THE safety circuits used on PLUTO are designed around the "2 out of 3" system, so that the number of instruments used in each monitoring channel must be increased as compared with a DIDO-type reactor. Because of the use of three guard lines, each of equal importance, again the number of prime contacts contained in each monitor has to be increased. An examination of the simplified diagram, Fig. 1, will illustrate this clearly. The remaining contact in each monitor is normally used for illuminating a local warning lamp.

To satisfy these new safety circuit design principles the prime nucleonic instrumentation requirements were then, in the three different levels of shut-down:—

Complete Shut-down (dropping of safety rods and control arms, closing of building seals):—

Three shut-down amplifiers set to emergency flux level.

Three monitors (gamma) measuring a selected point in the ventilation ducts (10-20 times alarm level).

Three similar monitors measuring another selected point in the ventilation ducts.

Three monitors (gamma) measuring health hazard at one selected point in the reactor shell (10-20 times alarm level).

Trip (control arms dropped):—

Three period meters monitoring the reactor doubling time.

Three shut-down amplifiers monitoring flux level lower than that for complete shut-down.

Three channels, in the misalignment amplifiers, per coarse control arm, measuring control-arm misalignment.

Control Reversal (control arms run in at fast speed):—

Is not influenced by flux or ancillary flux measurements, but only by physical measurements.

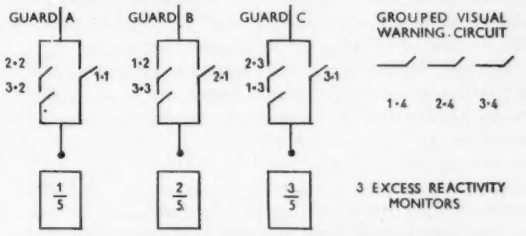
In addition to these systems of active safety circuits there are included passive safety circuits, or warning guards, for fault conditions in the reactor system not considered sufficiently serious to initiate any of the above shut-down actions, but which are required to give visual warnings in the control room, so that they can be corrected before developing to a major level and causing a reactor shut-down.

Neutron Flux Channels

A brief description of the flux-measuring and ancillary instruments is given below:—

Shut-down Amplifier Type 1461C. This unit is a conventional feed-back d.c. amplifier driving two normally energized relays in the anodes of a long-tailed pair. Diodes are arranged in the output circuit so that as the shut-down or trip level is reached the feed-back is effectively removed, which causes the circuit to develop full forward gain and rapidly de-energize one of the two relays. The unit is fed from a neutron-sensitive ion chamber, type RC.1, and incorporates self-test facilities at 1 MW and 10 MW equivalent input by injecting equivalent currents into the input circuit.

The actual trip level can be set at 1 MW and 5-15 MW in 1-MW steps. The instrument is designed to be as fully "fail-safe" as possible.



Simplified diagram showing prime contacts of monitoring devices and their disposal.

These instruments were modified from the IDL 1461B, to give a low flux start guard facility. This modification entailed the incorporation of another relay, switched by a signal from the safety circuit, which effectively changed the sensitivity of the instrument to give a trip at approximately 50 kW, so that, during shut-down, it is impossible to start the reactor if the shut-down power exceeds 50 kW.

Period Meter Type 1513B. This unit measures the flux and indicates it on a log scale, the indicated meter reading, i.e. output voltage, being proportional to the logarithm of the input current derived from a neutron-sensitive ion chamber.

To obtain period information and indication, the output from the log d.c. amplifier is fed via a fixed differentiating circuit to a second d.c. amplifier. The output of this amplifier is then displayed on a meter, calibrated in doubling time, both negative and positive going. The output also feeds a trip circuit which can be set to trigger at predetermined levels, these levels being adjustable to correspond to the minimum permissible reactor doubling time. More rapid changes of power, either decreasing or increasing, will cause the circuit to operate and thus pass information into the safety circuits.

Single-range Linear Power. This channel is inherently simple and safe, and consists of a neutron-sensitive ion chamber feeding direct into a high-input impedance Kent electronic potentiometric recorder fitted with a suitable input resistance.

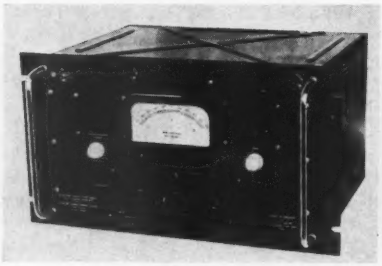
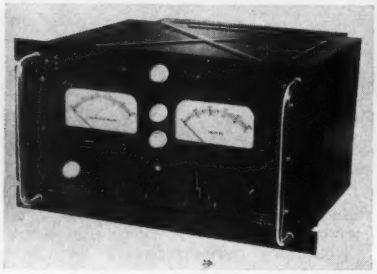


Fig. 2.—Deviation meter, type 1462A.

Fig. 3.—Ratemeter, type 1463A.



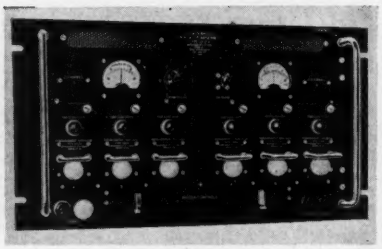


Fig. 4.—Misalignment indicator assembly type 1512A.

Multi-range Linear Power. The difference between this channel and the single-range linear channel mentioned above is that six input resistors, matched to cover six decades of power, are used, with associated switching so that each resistor may be selected in turn, to cover the total power range of the reactor.

Reactor Power-error Meter Type 1462A. This equipment is used to allow the reactor operator to set up, by switch units, the power required from the reactor. The instrument measures, and indicates, the difference between the demanded and actual powers, expressing the difference as a percentage of demanded power. In addition, the units also incorporate relay circuits for warning or trip usage, and an output suitable for automatic control.

Current from the neutron-sensitive ionization chamber is applied to the head unit, on which the required power is set by selection of input resistor. A voltage output is fed, therefore, to the main amplifier. This amplifier has overall feed-back and, in addition, is corrected for drift and stability by an associated chopper-driven a.c. amplifier.

The output of the stabilized d.c. amplifier is fed to a normal valve-voltmeter circuit, and this circuit is so arranged that the sensitivity of the instrument can be changed, by switching, so that the deviation from "Demanded Power" can be indicated as either 1%, 10% or 100% from the set "Demanded Power."

Health Monitoring.

Gamma Monitor Type 1529A. This unit consists of a Head Amplifier, comprising an Airwall Ionization Chamber Type 1506A and head amplifier coupled to a logarithmic amplifier, which functions similarly to the log amplifier in the Period Meter. That is to say, grid voltage changes on the electrometer valve try to change the anode current flowing in that valve. However, a d.c. amplifier is connected between anode and screen so that, as anode current tends to change, the applied screen voltage is changed to maintain anode voltage constant.

Since, due to methods of usage, the grid voltage is proportional to the log of the input current, the voltage applied to the screen is also proportional to the log of the input current. Associated with this amplifier are two relay circuits, one giving relay operation at 10 mr/h equivalent input current, and the other circuit being adjustable to operate over the range 10-10^5 mr/h.

A gamma radioactive source is strapped on to the airwall equivalent ionization chamber to maintain a minimum chamber output current corresponding to 1 mr/h, the instrument being so calibrated that the meter scale reads correctly for external radiation.

Fast Neutron Monitor Type 1463A. This equipment consists of a Head Amplifier, Fast Neutron, coupled to a Ratemeter Type 1463A. The first of these comprises a Fast Neutron sensitive Counter, Type FN2/2, which mounts direct on to the head amplifier casting. This casting houses:

(a) a head amplifier consisting of a ring of two with overall feed-back stabilizing the overall gain to a factor of 2;

(b) a meter, remotely driven from the main unit, calibrated in count rate;

(c) a warning lamp which, again, is driven from the main unit.

The Ratemeter Type 1463A comprises a wide-band amplifier, the gain of which can be set, in four steps, between 100 and 1,000 with a band width of greater than 2 Mc/s. This amplifier is followed by a voltage discriminator covering the range of 5 to 50 V, and thence to a ratemeter covering the range of 1, 3, 10, 30, 100, 300, 1,000, 3,000 and 10,000 pulses/sec, to be used in association with switched integrating time constants of 0.2, 1, 5, 20 and 80 sec.

The ratemeter output is fed to relay operating circuits and the level at which the relay circuit operates can be set anywhere between 1/4 F.S.D. and F.S.D. (of the ratemeter).

Fig. 5.—Reactor period meter, type 1513B.

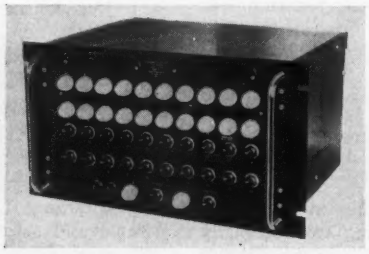


Fig. 6.—Leak indicator unit, type 1509A.

Fig. 7.—Battery box assembly, type 1510A.

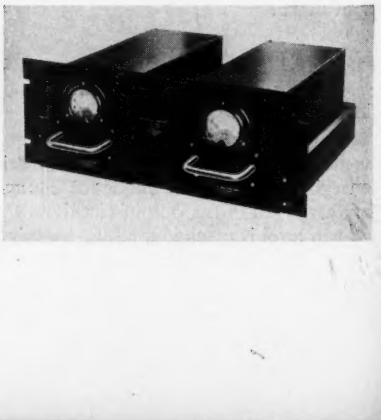


Fig. 8.—(Left) Two relay racks incorporating lock-out and bypass panel, and loop instrumentation panel.

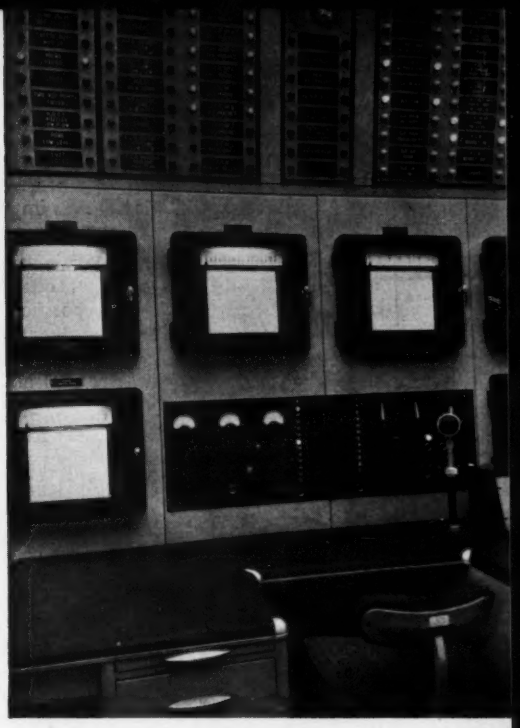


Fig. 9.—(Right) Main control panel.

In addition, an H.V. supply is also built in, capable of giving 350-1,000 V or 700-2,000 V.

Ancillary Measurements

D_2O and H_2O Gamma Activity. This measurement is carried out by using a normal Monitor Gamma Reactor Type 1529A.

D_2O leak into H_2O. A Scintillation Counter Type N559E, using a sodium iodide crystal, checks the gamma activity in H_2O coolant outlet pipes from the D_2O/H_2O heat exchanger. Any gamma activity indicated on the associated Ratemeter Type 1463A indicates a leak of D_2O into the H_2O, since, normally, the light-water coolant should be non-active.

External Leak of Heavy Water

Leak Indicator, Type 1509A. A leak detector, consisting essentially of two metal foils separated by absorbent material, is wrapped around each coupling or joint flange of the D_2O circuit. The metal foils are connected between ground and input grid of one of the 20 channels in each indicator unit. When the absorbent separating material is dry, then the resistance between the two foils is sufficient to keep the grid only just negative with respect to its cathode. On a D_2O external leak occurring, the resistance of the separating material falls, due to absorbed moisture, and the grid moves negative with respect to the cathode. At a certain sub-normal value of insulation the grid is sufficiently negative with respect to the cathode to cut the valve off. This drops out the anode-driven relay and thus the leak information is passed on to alarm circuits and warning lamps.

Coarse Control Arm Misalignment Monitoring. It is essential, in this reactor, that there be no large flux perturbations or changes in flux distribution through the reactor because of different positions of the seven coarse control arms.

The Misalignment Indicator, Type 1512A, is used for monitoring the alignment and tripping the reactor if the misalignment of any arm exceeds the permitted amount of 4 min of arc at the arm itself.

A master transmitter magslip is housed in the master gearbox of the coarse control-arm circuit. This transmitter is excited by approximately 30 V a.c., derived from one of the Misalignment Indicator Units. Its stator is connected in parallel with the stators of seven slave magslips, one in each coarse control-arm slave gearbox. Then the rotor output of each slave magslip feeds one of the channels of misalignment indication with a signal, the phase and amplitude of which is proportional to the direction and degree of misalignment. This signal drives a two-valve relay circuit, which is set to operate at the above-mentioned trip level. Since the equipment is used in a 2 out of 3 safety system, each coarse control-arm slave magslip feeds three separate relay circuits, and two of these three circuits must be in a tripped condition before a reactor shut-down occurs.

Telemetering

Coarse Control Arms Position Indication. The master gearbox mentioned above carries two additional transmitter magslips which are used for control arm position indication, both coarse and fine.

One magslip is geared to give complete movement of a control arm in approximately one revolution, i.e., coarse position indication, and the other is geared to give 1° of movement for approximately one revolution, i.e., fine position indication. These two magslips each drive a receiver magslip assembly on the control panel, thus enabling the operator quickly to see the transmitted position of the arms in the reactor.

Fine Control Rod Position Indication. This, in principle, uses the same remote indicating system as for the control arms, but only coarse position is indicated, i.e., total control-rod movement is covered in less than one revolution of the receiver magslip.

Safety Rod Position Indication. The safety rods should either be fully out or fully in, and thus lamps are used to indicate these two positions, driven from limit switches in the safety rod drive units. However, since the operator is also interested in their positions whilst they are being lifted out, a meter, driven by a potentiometer in the drive unit, is used to give the safety rod position whilst they are in transit.

Control Circuits

For any new system to be an improvement on the DIDO system it had to satisfy three basic principles, which can be itemized as:—

(i) **Safety.** For maximum safety, the number of elements operating in an identical capacity should be a maximum, with each element capable, in its own right, of

causing a shut-down. This, again, means that, accepting that a number of elements fail unsafe, a number of elements are still in a safe condition. This implies serious connection of elements.

(ii) **Spurious Shut-down.** Again, the requirement is a maximum number of elements operating in the same capacity, but here each must not be capable of causing shut-down, i.e., a maximum number of elements can fail safe before spurious shut-down occurs. This implies parallel connection of elements; (i) and (ii) are therefore directly conflicting requirements.

(iii) **Maintenance.** Obeying the criteria of (i) and (ii), it must be possible to do maintenance and repair to the reactor control and safety circuits whilst the reactor is on load.

As usual, a compromise can be arrived at by considering probability of failure, and cost, and complexity, having due regard to the fact that increasing complexity is not, practically, linearly related to increased reliability and safety.

In order to consider both safety and spurious shut-down in any one system it is necessary to introduce the principle of a " N out of M " system, where N is the minimum number of elements, in a group of M elements, which must operate normally (or fail safe) to cause shut-down.

The simplest system which can be produced without going into detailed arguments, requires:—

$$M-N=1 \text{ and } N-1=1$$

(i.e., a 2 out of 3 system)

The simplified diagram, Fig. 1, will be seen to satisfy these requirements, both as far as contact grouping is concerned and as far as monitor grouping is concerned also.

The suggestion to use a 2 out of 3 system was accepted by A.E.R.E., but the application of it to PLUTO was again a compromise.

The building programme was very tight, and because of this—also from the cost point of view—the system used had to be d.c., although an a.c. system is preferable. Also, the industrial monitors, i.e. flow, pressure, temperature monitors, etc., which are available in most cases had insufficient contacts available to satisfy the 2 out of 3 contact requirements. In addition, the physical monitoring elements have a bias towards failing unsafe, rather than safe (although the probability of failure is low compared with electronic elements). It was, therefore, necessary to arrange the physical elements in a 1 out of 3 system, where these elements could not take an electronic form.

Where this system of grouping is used, these elements are put into " B " guard lines with monitoring relays at both ends of each of these lines. The contacts provided by these monitoring relays are then grouped in a 4 out of 6 arrangement in the " A " guard lines, so that a 2 out of 3 " B " guard-line operation is required before the " B " line contacts in the " A " guard lines operate at least 1 out of the 3 " A " guard lines.

In order of shut-down importance, the guard-line grouping is as follows:

(a) Complete shut-down—" A " guards only.
(b) Trip " A " lines.
(c) Trip " B " lines.
(d) Control Reversal " A " lines.
(e) Control Reversal " B " lines.
(f) Warning circuits.

A general arrangement of the trip " A " guard lines and trip " B " guard lines is given in the accompanying article by Walker and Liddiard (p. 143). It can be clearly seen from this outline how the " B " line contacts are in a series arrangement, with the two ends of each of the guard lines monitored by the A-F relays. Reference, then, to the " A " guard-line sequence shows how electronic monitor contacts are arranged in a 2 out of 3 system, with the contacts of the A-F relays in a 4 out of 6 system.

It can also be seen that the " A " guard lines will only shut the reactor down if either two or more similar electronic monitors have failed safe or operated on a genuine dangerous reactor state, or if two or more " B " guard lines have operated. Conversely, it can be seen that failure to safety of one element in either " B " lines or " A " lines will not cause a spurious shut-down; nor will failure unsafe of one element in either " B " or " A " lines prevent the reactor shutting down if a genuine state of reactor abnormality arises.

Interlock. This item is used to cover that system of control circuitry which ensures, automatically, that all

EQUIPMENT SCHEDULE

Panel No.	Description
1	Fuse panel.
2	Ratemeter (1463A). Leak detector (1509A). Leak detector (1509A). Leak detector (1509A) (spare). Leak detector (1509A) (spare).
3	Recorder (burst fuel). Recorder γ health. Log d.c. amplifier (1529A), health. Log d.c. amplifier (1529A), heaith. Log d.c. amplifier (1529A), health.
4	Recorder—γ D_2O and H_2O. Recorder—γ, health. γ Health amplifier (1529A). γ Health amplifier (1529A). γ Health amplifier (1529A).
5	Recorder—D_2O in H_2O. Recorder—D_2O purity. γ Health amplifier (1529A). γ Health amplifier (1529A). γ Health amplifier (1529A).
6	Recorder—D_2O o/c temperature. Flow meter—D_2O flow. Error meter 1462A. Error meter 1462A.
7	Recorder—D_2O temperature. Recorder—C.C.A.
8	Recorder—Multi line. Left-hand panel scheme.
9	Recorder—Log power. Right-hand panel scheme.
10	Recorder—Centre fuel element temp. Recorder—Fine control-rod position.
11	Recorder—H_2O inlet temp. Flow meter—H_2O flow. Period meter. Period meter.
12	Recorder—Linear integrator. Recorder—Computed power. Period meter. Period meter.
13	Pressure meter. Pressure D_2O/H_2O. Pressure meter. Pressure R.A.T. Shut-down amplifier (1461B). Shut-down amplifier (1461B). Shut-down amplifier (1461B).
14	Recorder—Fuel element temp. Recorder—Fuel element temp. Shut-down amplifier (1461B). Shut-down amplifier (1461B).
15	Recorder—Shield temperature. Switch box. Safety-rod indicator unit. Shut-down amplifier spare (1461B). Shut-down amplifier spare (1461B).
16	Misalignment indicator (1512A). Misalignment indicator (1512A). Misalignment indicator (1512A). Misalignment indicator (1512A). Error meter 1462A.
17	Ratemeter (fast neutrons) (1463A). Ratemeter (fast neutrons) (1463A). Ratemeter (fast neutrons) (1463A). Ratemeter (fast neutrons) (1463A) (spare). γ Health amp. (1529A) (spare).
18	Ratemeter (fast neutron) (1463A). Ratemeter (fast neutron) (1463A). Ratemeter (fast neutron) (1463A). Ratemeter (fast neutron) (1463A) (spare). γ Health amp. (1529A) (spare).
19	Liquid level meter receiver indicator. Liquid level meter indicator. Pump C.P. D_2O purity amp. (A.E.R.E.). Bailey amp. (H.F.E. temp. trip).
20	Xenon recorder. Xenon recorder. Switch box. Xenon amp. A.E.R.E. P/A amp.
21	Experimental. Recorder pH. Xenon amp. Xenon amp. Stowage.
22	Recorder. Flow meter D_2O. D_2O γ activity—γ health (1529A). H_2O γ activity—γ health (1529A). γ activity (spare).
23	Battery box storage 1510.
24	Power cabinet.
25	Ratemeter (D_2O in H_2O) 1463A. Ratemeter (D_2O in H_2O) 1463A. Ratemeter (D_2O in H_2O) 1463A. Ratemeter (D_2O in H_2O) 1463A (spare). Stowage.
26	γ Health d.c. log amp. 1529A. γ Health d.c. log amp. 1529A. γ Health d.c. log amp. 1529A. γ Health d.c. log amp. 1529A. γ Health d.c. log amp. 1529A. γ Health d.c. log amp. 1529A. γ Health d.c. log amp. 1529A (spare).
27	γ Health d.c. log amp. 1529A. γ Health d.c. log amp. 1529A. γ Health d.c. log amp. 1529A. γ Health d.c. log amp. 1529A. γ Health d.c. log amp. 1529A. γ Health d.c. log amp. 1529A. Stowage.

aspects of reactor operation have to follow a definite laid-down sequence. A typical example of this is:

Operation of Coarse Control Arms. These can be raised provided:

(a) Safety rods are fully raised out of the reactor,
(b) dump valve is fully closed,
(c) fine control rod is raised past the " nearly in " position,
(d) no trip conditions exist,
(e) the fine control rod is not in motion.

In addition to these interlocks, governing reactor control element state, the coarse control arms can only operate, after the necessary push-button has been pressed, for a maximum period of 2 min. This check is carried out by an in-built time guard. After this time guard has operated, then it is necessary to press the relevant push-button again to obtain further coarse control arm movement.

Maintenance

Maintenance on the reactor proper, as distinct from maintenance of monitors and safety circuits, can only be done whilst the reactor is shut down. In order to ensure that this is so, a positive system of key locking is used. Access to the Lock-out and By-pass panel can only be obtained if the master key from the control panel is removed, to unlock the door to the Lock-out and By-pass panel. Again, the design principles for maintenance facilities follow standard A.E.R.E. practice, to ensure at all times that the reactor is in a safe condition.

Loop Elements

Rather large experimental loops can be built into the reactor. As these might prejudice reactor safety, if an incident occurred on one of these loops, the loop instrumentation can pass information into the main control and safety circuits by simply plugging this instrumentation information into the loop plug panel.

Control-room Layout

As will be seen from the illustrations, the control circuitry has been made, in effect, plug-in type. The relay circuitry is divided into 13 relay sets, each of which is back plugged into the two relay main structures, which also house: (a) the " Lock-out and By-pass " panel on which all maintenance switching is carried out; (b) the loop panel into which experimental loop instrumentation can be plugged to form part of the main safety and control circuitry; (c) the " flexibility " panel, which is used to combine the different sections of the three guard lines in a predetermined order, and which therefore allows for alteration of the guard line circuitry without changing permanent wiring.

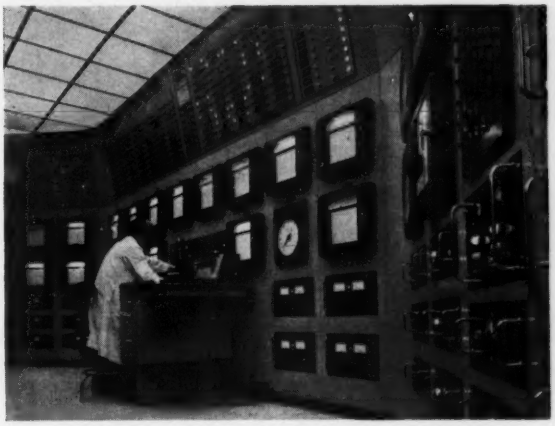


Fig. 10.—View of control room from right-hand side.

The two relay panels are followed, from left to right, by a block of four instrument panels (Nos. 1-4), then a block of eight (Nos. 5-12) and a further four (Nos. 13-16), forming the most important side of the control room, i.e., the side at which the pile operator sits. The other side of the control room is then made up of two blocks of instrument panels (Nos. 17-19 and Nos. 20-22) against Face 2 of the reactor.

Outside the control room, panel 23 is against Face 1, and panels Nos. 24-26 are underneath the platform and adjacent to 3V8.

The panels are equipped as shown in the schedule. The operational control panel as such bridges panels 8-9. The left-hand panel is concerned primarily with nuclear power measurement indication; the right-hand panel is associated with reactor power control, and the centre panel shows the shut-down state of the reactor.

Acknowledgments are due to the Directors of Ekco Electronics Ltd., for permission to publish this article, and to colleagues, past and present, for their assistance in preparing it.

L'Instrumentation Nucléaire de Pluto

L'article donne les grandes lignes de l'instrumentation nucléaire effective de Pluto et décrit les appareils employés et la méthode de fonctionnement des dispositifs de contrôle employés pour la protection et la sécurité, ainsi que les précautions sanitaires, et aussi l'équipement de télémesure employé pour l'indication de la position des tiges de contrôle.

Les principes du système "2 sur 3" employé pour assurer une sécurité absolue de fonctionnement sans disjonction erroné sont énoncés, et on y fait mention de ce qui a été prévu pour faire l'apport des renseignements obtenus de l'instrumentation des boucles à l'essai.

Die Ausrüstung des Werkes Pluto mit Instrumenten zur Anzeige von Vorgängen in den Atomkernen

Der Aufsatz zeigt die Ausrüstung mit Instrumenten zur Anzeige von Vorgängen in den Atomkernen, wie sie im Werk Pluto ausgeführt ist, und beschreibt die Apparatur, die benutzt wird, ferner die Methode, nach der die Ueberwachungs-Organe funktionieren, die zum Schutz der Sicherheit und der Gesundheit eingebaut sind, schliesslich die Einrichtung zur Fernanzeige der jeweiligen Stellung der Regulierungs-Stäbe.

Es werden die Grundsätze erörtert, die nach dem System " zwei-von-drei " gewählt sind, um absolute Sicherheit des Betriebes zu gewährleisten, sodass keine Fehl-Schaltungen vorkommen können, und es wird erwähnt, welche Einrichtungen getroffen sind, um die Anzeigen der Instrumente in den Umläufen, in denen Versuche gemacht werden, zu übertragen.

La Instrumentación Nuclear de Pluto

Este artículo hace un bosquejo de la instrumentación nuclear efectiva de Pluto y describe los aparatos empleados y el método de funcionamiento de los monitores usados para protección de seguridad y precauciones para salvaguardar la salud, así como el equipo telemétrico empleado para indicación de la posición de la varilla de control.

También se explican los principios del sistema de "2 de 3" empleado para lograr absoluta seguridad en el funcionamiento sin falsos disparos, y a la par se citan las medidas provistas para alimentar la información de la instrumentación de los lazos sometidos a prueba.

Britain's Heavy Water Reactors

Six in Service or on Order—

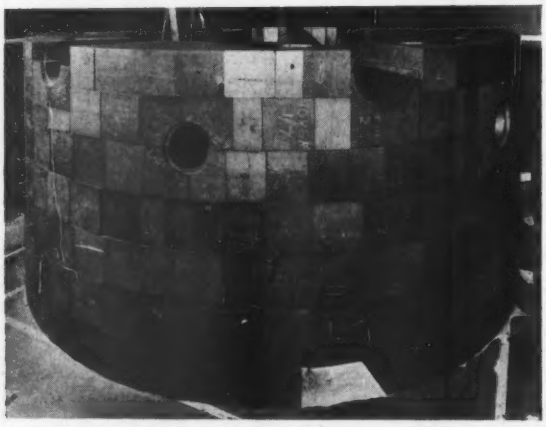
Three for Overseas

THE first of the British heavy water reactors was, of course, DIDO which had its official opening in November, 1956. It may be argued that DIDO stems from Canada's NRX which achieved operation as far back as July 22, 1947. There is a certain superficial resemblance —as there must inevitably be with any tank-type reactor— but it is superficial only. NRX, due to its use of natural uranium achieves a flux density of 6.8×10^{13} with a power rating of 40 MW. It has been estimated that had DIDO utilized natural uranium, its maximum neutron flux density would have required a power output of 100 MW, which would have been exceedingly costly and inconvenient to get rid of. By the use of fuel of high enrichment it was possible to obtain a flux of 10^{14} n/cm²-sec with a power of only 10 MW.

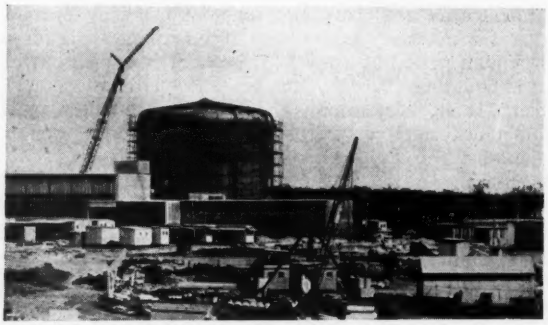
The reactor and its associated plant and buildings, incorporating a number of advanced conceptions in safety and convenience of operation, was designed by an AERE team in conjunction with the Ministry of Works and Head Wrightson Processes Ltd. It was briefly described in *Nuclear Engineering* for December, 1956, following its official opening. In January, 1957, the engineering aspects were discussed at some length, and it formed the subject of No. 8 in the "World's Reactors" series.

DIDO's functions are, of course, research and a certain amount of isotope production rather than materials testing, and it is designed with a comparatively large number of experimental facilities of comparatively small dimensions.

Following on the commencement of construction of DIDO, two other reactors were designed primarily for materials testing, and arranged with fewer and larger experimental facilities. These were PLUTO, located at Harwell, quite near to DIDO; and DMTR, the Dounreay Materials Testing Reactor. These are generally of the DIDO type, except in minor details, and the use of a rectangular prism form for the main concrete shield, in place of the 10-sided prism used for DIDO. The experimental facilities are compared in Table 1 on this page.



Pre-assembly of graphite reflector for HIFAR.



A general view of the HIFAR site at Lucas Heights near Sydney.

DMTR was described in *Nuclear Engineering* for July, 1957, and PLUTO in December of the same year. PLUTO forms the subject of the pull-out on the opposite page.

Overseas Installations

The DIDO-type reactor is hardly likely to become a mass-production off-the-shelf article. Nevertheless, it is a marketable proposition, as instanced by the orders from overseas, bringing the total number up to six. The other overseas reactors are HIFAR (High Flux Australian Reactor), installed by the Australian Atomic Energy Commission at Lucas Heights, Sydney; and DR3 (Danish Reactor No. 3), a PLUTO-type reactor under construction in Denmark.

A contract was signed last October between Head Wrightson Processes Ltd., and Land-Nordrhein-Westfalen for a DIDO-type reactor for the L-N-W Atomic Research establishment in the Federal German Republic. It will be at the disposal of the universities of Aachen, Bonn, Cologne and Muenster.

TABLE 1. COMPARISON OF EXPERIMENTAL FACILITIES

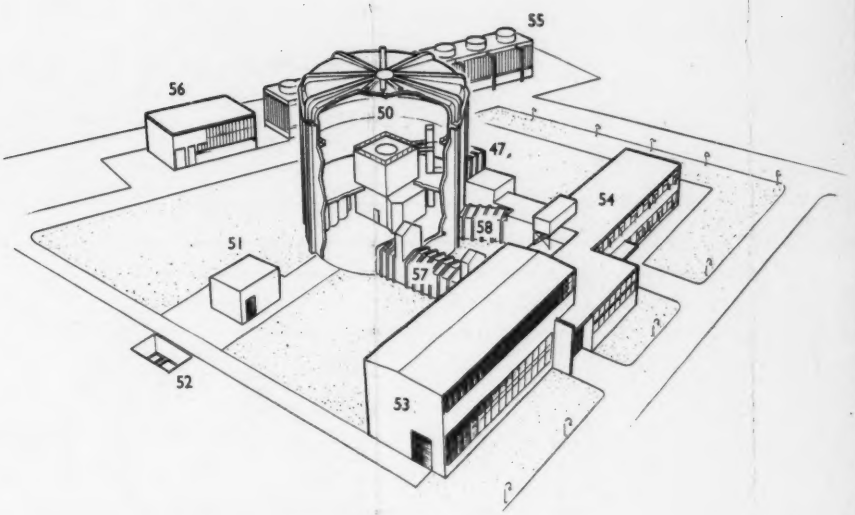
Description	Size	DIDO HIFAR L-N-W	PLUTO DMTR DR3
Horizontal			
In D_2O	10 in. dia.	1	–
In D_2O	6 in. dia.	1	–
In D_2O	4 in. dia.	6	–
In D_2O (right through)	7 in. dia.	–	4
In D_2O (right through)	Oval 4 in. × 2 in.	1	–
	Rectangular		
In graphite (right through)	8 in. × 12 in.	2	–
In graphite entering reflector only	6 in. dia.	10	–
Thermal Column	5 ft × 5 ft	1	–
	4 in. × 4 in.	9	–
Vertical			
In D_2O	7 in. dia.	–	4
	6 in. dia.	4	–
	4 in. dia.	5	4
	2 in. dia.	9	–
In graphite	10 in. dia.	2	–
	6 in. dia.	6	–
	4 in. dia.	2	6

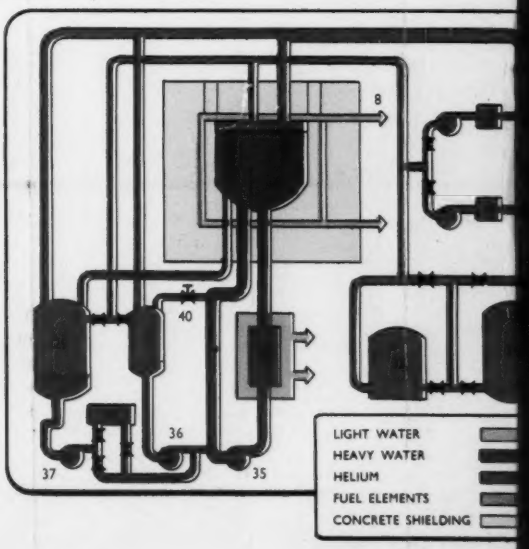
The World's Reactors

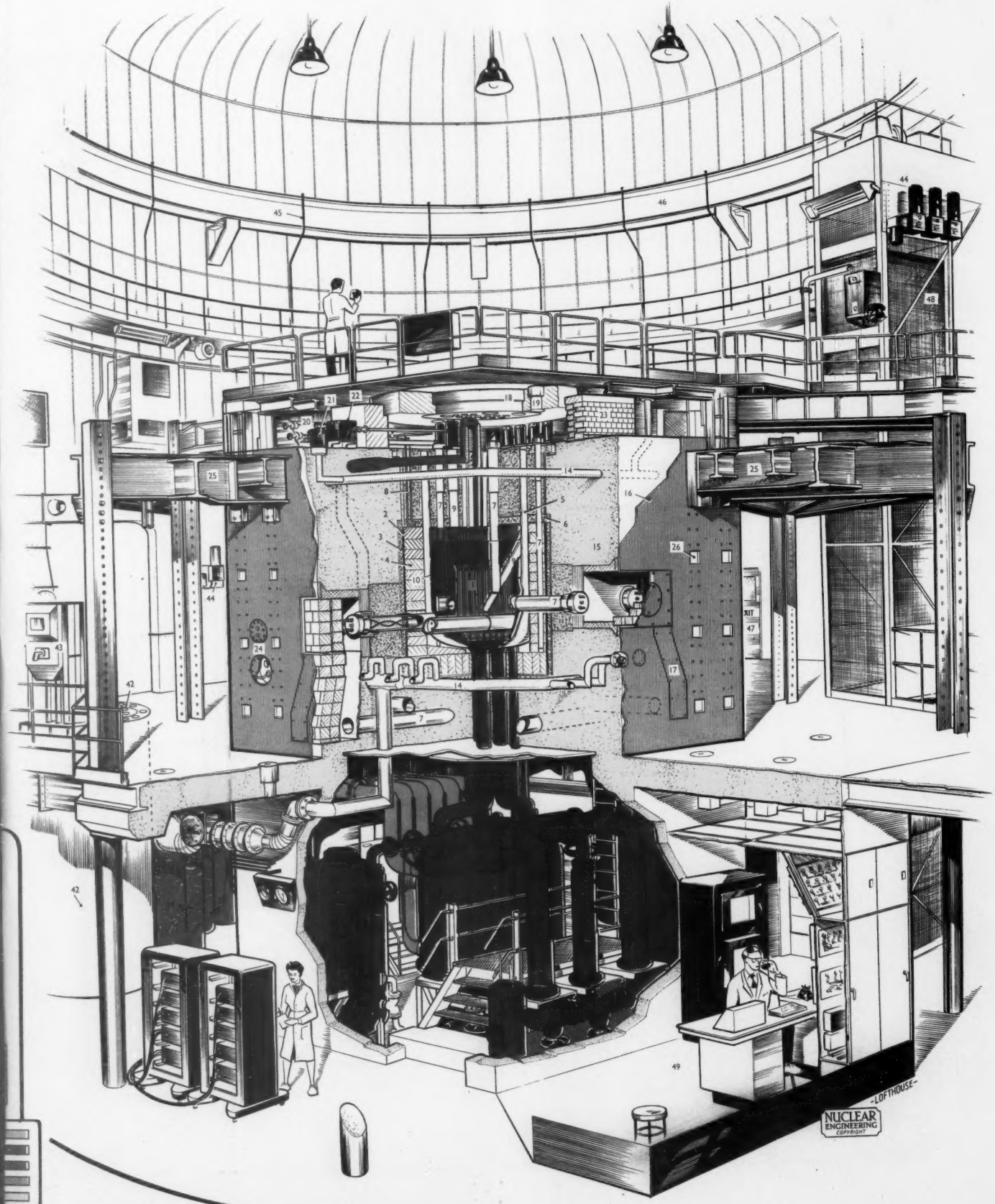
No. 16 PLUTO

KEY

1. Fuel elements
2. Steel thermal shield
3. Lead gamma shield
4. Graphite reflector
5. Aluminium reactor tank
6. Steel tank
7. Experimental facilities
8. Gamma shield cooling
9. Coarse control arm
10. Heavy water level pipe
11. Heavy water inlet pipes
12. Heavy water outlet pipes
13. Helium duct
14. Air ducts
15. Biological shield
16. Steel outer casing
17. Removable access plates
18. Top plate
19. Access plug
20. Fine control rod cooling pumps
21. Fine control rod drive
22. Coarse control arm drive
23. Removable shielding
24. Ion chamber holes
25. Movable floor
26. Movable floor locating pockets
27. Heavy water coolers
28. Heavy water circulating pumps
29. Heavy water storage vessel
30. Shut down pump
31. Dump tank
32. Main tank
33. Helium gas holders
34. Expansion tanks
35. Main circulating pump
36. Transfer pump
37. Liquid level control pump
38. Recombination unit
39. Helium purifying unit
40. Dump valve
41. Ion exchange unit
42. Active element storage
43. Fuel element assembly station
44. Health monitors
45. Decontamination water sprays
46. Crane track
47. Emergency exit
48. Lift
49. Control room
50. Sealed Reactor building
51. Emergency control
52. Delay tanks
53. Active area building
54. Laboratories and offices
55. Cooling towers
56. Water treatment building
57. Vehicle airlock
58. Personnel airlock






NUCLEAR ENGINEERING
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TYPE:

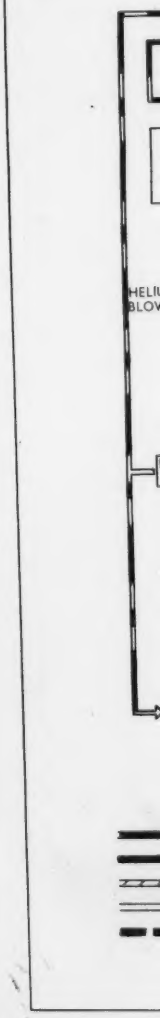
PURPOSE:

RATING:

LOCATION:

OPERATION:

FUEL:



The World's Reactors

No. 16 PLUTO

:
Thermal heterogeneous.

POSE:
High flux materials testing.

NG:
10 MW.

ATION:
A.E.R.E., Harwell, England.

RATION:
Critical, October 25, 1957.

:
Enriched uranium alloy, box type.
Alloy: uranium-aluminium, aluminium clad.
Core form: 23.75 in. × 2.36 in. × 0.018 in.
Curvature: on radius, 5¼ in.
Assembly: 2.9 in. sq. approx., ten plates per box.
Total investment: 2.6 kg.

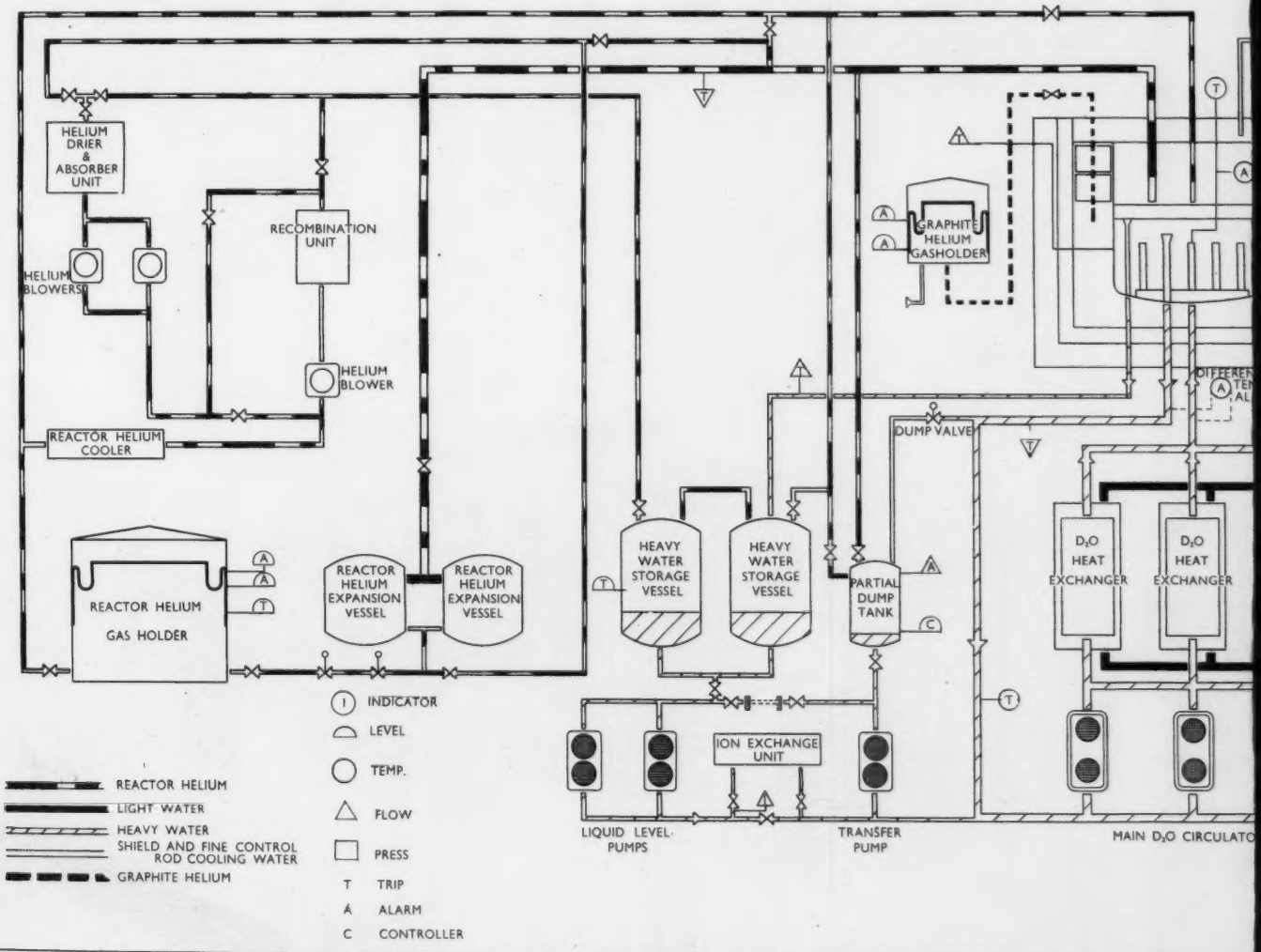
CONTROL:
Coarse control/shut-off: seven in numb
Construction: 0.080-in.-thick cadmium
S.W.G. stainless-steel sheet.
Signal arm: 4 ft. 7⅜ in. long.
Fine control rod: one in number.
Construction: 24 in. long, 255 cm.², cy
stainless-steel tubes.
Safety rods: two in number.
Construction: Stainless-steel tube c
cylinder, 33 in. long.

CLADDING:
Aluminium: SIC.
Treatment: Aluminium sheet, welded o

MODERATOR:
Heavy water.
Total investment: 10 tonnes.

CORE:
Reacting core: 27 in. × 33 in. × 24 in. hi
Core tank: 99.8% purity Al., 6 ft. 7 in.
Lattice: basically square.
Number of fuel elements: 26.

REFLECTOR:
Graphite.
Segmental blocks, lead bound.
Radial thickness: 12 in.



MIMIC DIAGRAM IN CONTR

control/shut-off: seven in number.
uction: 0.080-in.-thick cadmium sheet, welded between 20
G. stainless-steel sheet.
rm: 4 ft. 7⅞ in. long.
ntrol rod: one in number.
uction: 24 in. long, 255 cm.², cylinder contained between two
less-steel tubes.
rods: two in number.
uction: Stainless-steel tube containing 1094-cm.² cadmium
der, 33 in. long.

ium: SIC.
ent: Aluminium sheet, welded on three sides, rolled.

water.
nvestment: 10 tonnes.

g core: 27 in. × 33 in. × 24 in. high.
nk: 99.8% purity Al., 6 ft. 7 in. diameter.
: basically square.
r of fuel elements: 26.

te.
tal blocks, lead bound.
thickness: 12 in.

COOLANT: Heavy water.
Flow rate through elements: 10 ft./sec.

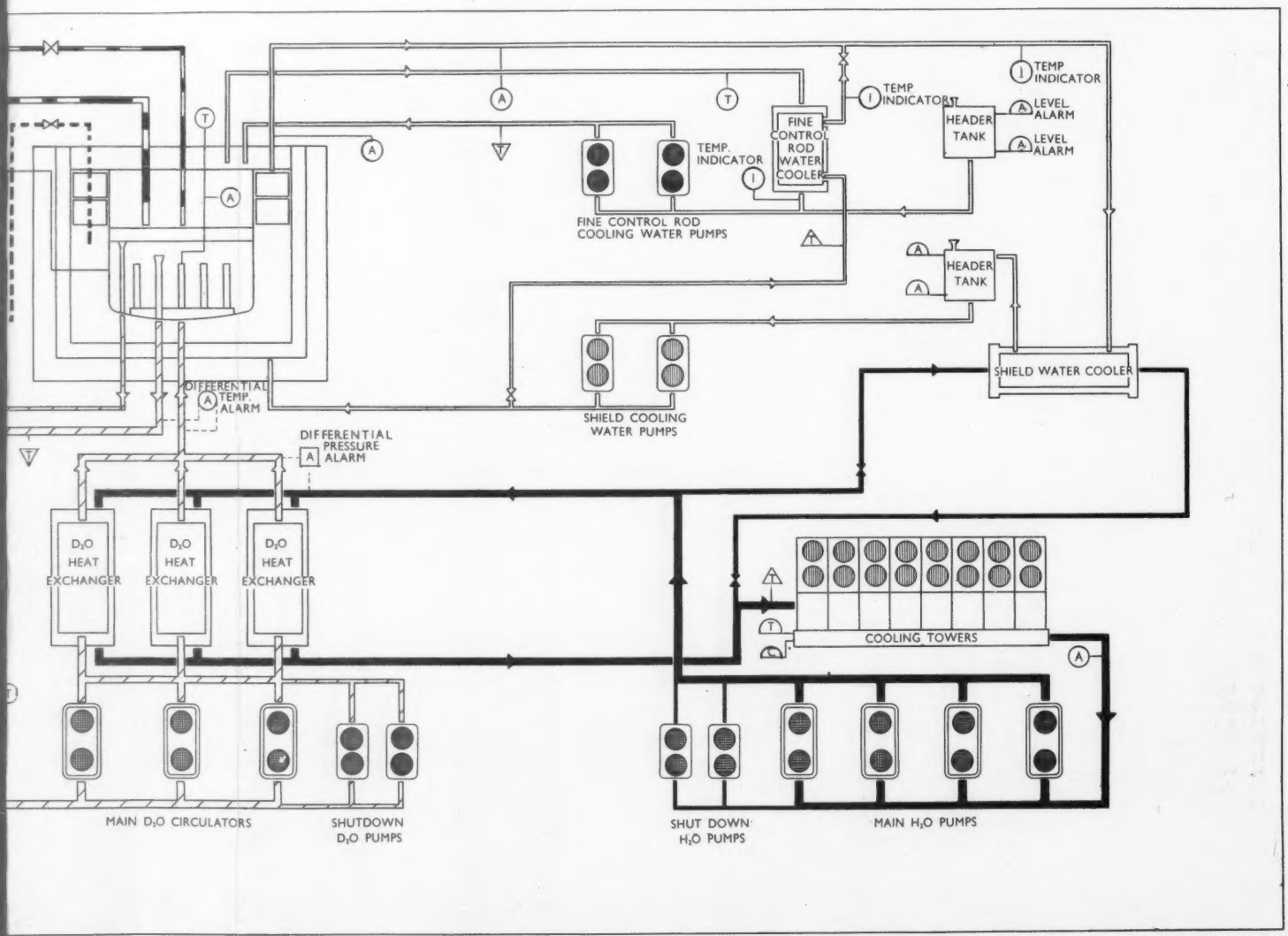
FLUX: Maximum thermal neutron flux: 10^{14}n/cm²-sec.

SHIELDING: Top: Inner: 2mm. cadmium; 4 in. water-cooled lead.
Intermediate: concrete.
Outer: cast iron and steel.
Side and bottom:
Inner: boral plates.
Intermediate: steel tank 9 ft. 0½ in. I.D. × 12 ft. 5 in. high, skin thickness 1 in., 2-in. bottom plate, 4-in. water-cooled lead between skins.
Outer: Barytes and heavy concrete, 5 ft. thick.

OVERALL SIZE: Rectangular prism 20 ft. across flats; height 35 ft. 3 in. overall.

OUTER SHELL: Steel building, 70 ft. diameter, pressurized at ⅛ in. W.G. below atmosphere.

EXPERIMENTAL FACILITIES: *Horizontal:* 4–7 in. dia., right through D_2O.
Vertical: 4–7 in. dia. and 4–4 in. dia. in D_2O; 6–4 in. dia. in graphite.



AGRAM IN CONTROL ROOM

PLUTO—Measurement and Control—3

PHYSICAL INSTRUMENTATION

By L. C. WHALLEY
(*George Kent, Ltd.*)

The physical instrumentation of a reactor, although generally consisting of conventional types of instruments, is, nevertheless, an integral part of the control and safety system, and represents a very considerable portion of the total instrumentation.

PHYSICAL, as opposed to nuclear, instrumentation on a reactor such as PLUTO involves the measurement of flow, pressure, pressure difference, level, temperature, pH, and conductivity. As this is a research reactor and a considerable amount of operational flexibility is required, a very large number of instruments are involved and many of the measurements are associated with electrical trips or alarms for safety reasons.

The main circuits of the reactor are shown in simplified form on the pull-out immediately preceding this article.

Besides the emphasis of safety, special considerations were given to those parts of the instruments in contact with the heavy water and reactor helium. The reactor is designed for a high neutron flux and reactivity and corrosion considerations require a very high purity of the heavy water as measured by the D_2O purity recorder, i.e., 99.5 to 100%. The instruments in contact had to be to almost surgical standards of cleanliness, produced by machining and/or acid pickling, detergent and clean-water washing, and followed by the fitting of steel flanges and neoprene gaskets and inserting in sealed polythene bags to maintain cleanliness during transit. The materials for parts in contact were limited to 18/8/1 stainless steel or pure aluminium with gaskets in neoprene or P.T.F.E. All welding was required to be carried out by the argon-arc process, while tests included radiography of castings and welds, hydraulic pressure testing, air-under-water testing for leaks, and vacuum testing.

Presentation

Fig. 1 illustrates part of the control room and indicates that the panels form the walls of the room. The centre sections of the panels contain the most important instruments and include the D_2O and H_2O temperature recorders, the centre fuel element temperature recorder and the D_2O purity recorder. The panels are of unit construction, bolted together and continued upwards inside the control room to a false ceiling and outside to room ceiling. Closure panels and half-glass doors complete the control room. All the recorders illustrated are Multelec instruments and all the circular indicators are Commander Class receivers. Of the latter, those indicating flow or level of heavy water are readily recognizable by their black dials with white markings, figures and pointers. Pneumatic transmitters are used for the transmission of measurements to instruments in the control and emergency control room.

Two Mimic diagrams are included in the panels. One illustrates the ventilation system and by means of coloured lights shows the position of valves, whether fans are operating, etc. The other illustrates the helium, heavy-water and light-water circuits and, by means of coloured lights, shows the operator which pumps are running, as well as the valve positions, etc.

Two important measurements are transmitted to indicators in the emergency control room. These are the level of D_2O in the reactor and the pressure of the helium above the heavy water in the reactor.

Heavy-water Circuit

Because of their compactness, combined with low head loss, Dall tubes (7-in. size) are fitted in each of the four main D_2O outlets from the reactor. The total flow of D_2O is indicated both inside and outside the control room, while pressure switches enable low-flow trips to operate at both 90% and 30% of the normal flow rate.

The D_2O level in the reactor tank is measured by means of a differential pressure transmitter, transmitting to an indicating receiver in the control room. High-level alarm is provided.

Under normal conditions a steady overflow of D_2O from the reactor to the storage vessel is maintained by one of the liquid level pumps. Loss of overflow is detected by means of level electrodes located in a weir plate housing forming part of the overflow line.

The upper layer of heavy water in the reactor acts as a reflector and has a considerable effect on the reactivity; it can be run off into the partial dump tank by opening the dump valve. In normal operation this valve is closed by an electromagnet. When this is de-energized by remote switching from the control room, a weighted arm, attached to the valve stem, causes rapid opening of the valve.

Under normal conditions any D_2O leaking past the closed dump valve is returned to the reactor by means of the transfer pump, which operates in response to signals initiated by the level controller fitted to the partial dump tank.

When the dump valve has been opened, an electrical interlock prevents the controller operating the pump. Interlocks ensure that the transfer pump cannot be restarted until certain safety conditions have been met. A ball float level instrument provides alarm should the D_2O level in the partial dump tank slightly exceed the normal controlled level.

The level of D_2O in the main storage vessels is measured by means of a differential pressure transmitter with indicating receiver on the main panel. Two pressure switches are included to operate on low level.

The rate of flow through the ion-exchange unit is measured by means of an orifice and transmitter, with an indicator on the main panel.

An instrument in the control room records the temperature of the D_2O at the outlet from the reactor and, in addition, three amplifiers operate trip relays in the event of high temperature. A further instrument in the control room records the temperature difference between the D_2O at the inlet and outlet of the reactor. Here, also, three amplifiers operate trip relays in the event of high temperature difference.

A locally mounted three-point temperature indicator with visible and audible high temperature alarm at the

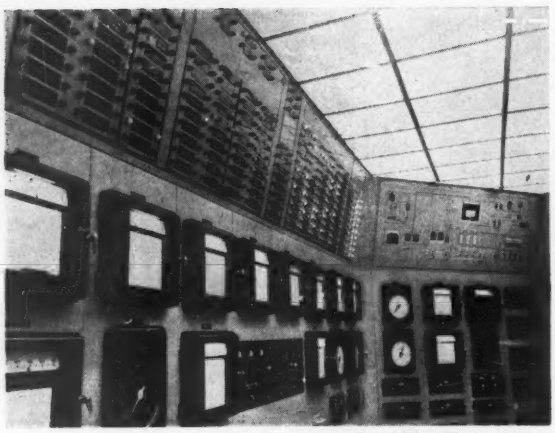


Photo : Ekco-Electronics, Ltd.

View of part of control panel at R.H. end, showing alarm panel on left and mimic diagram at far end.

main panel is connected to thermocouples inserted in the windings of the three main D_2O pumps.

Pressure indicators mounted near the main and emergency D_2O pumps show the discharge and suction pressures.

At the D_2O/H_2O heat exchangers it is necessary to prevent the possibility of light water leaking into the heavy-water circuit and passing into the reactor. The pressure of the heavy water is maintained at a higher value than that of the light water so that, should a leak occur, the heavy water will flow into the light water and will be detected by means of its radioactivity. Two pressure transmitters, one for D_2O and the other for H_2O, measure the pressures at the heat exchangers and the difference in pressure (i.e., D_2O-H_2O pressure) is obtained through a subtractor unit which transmits the pressure difference to an indicator in the control room, while a pressure switch gives a warning to the operator in the event of low pressure difference.

A three-point conductivity recorder measures the conductivity of D_2O at three different locations: (1) in the overflow line from the reactor to the storage vessel; (2) before the ion-exchange unit, and (3) after the ion-exchange unit. The instrument is suitable for two ranges (i.e., 0-2 and 0-50 reciprocal megohms), with manual range change, and is provided with alarm contacts operating on high conductivity at any of the three locations. The conductivity cells are in stainless steel with gold electrodes for direct insertion in the pipelines.

The continuous measurement of pH of D_2O (more accurately known as pD) presented many problems; the most important of these and how they were overcome are discussed below.* The very high purity of the D_2O in the reactor circuit had to be maintained, and because of contamination (mainly from the KCl out of the salt bridge of the reference electrode) it was decided to adopt a bleed-off system to the primary element, followed by collection and purification under a helium atmosphere, before returning the very costly D_2O into the main circuit. This introduced a need for extremely low rates (10-15cm³/h) of bleed-off, to reduce the volume of D_2O requiring purification.

The two main considerations were, therefore, the low conductivity and the low sampling rate, which introduced the following problems:—

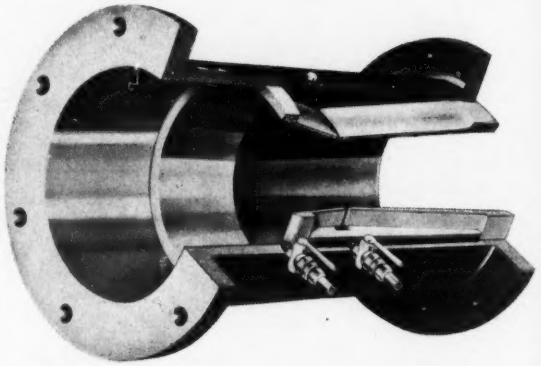
(1) Because of the low sampling rate: An increase in time lag.

(2) Because of the low conductivity and low sampling rate: Contamination of the D_2O and glass electrode by KCl; contamination of the D_2O surrounding the glass electrode by alkali from the glass electrode bulb (formed by solubility with D_2O).

(3) Because of the low conductivity: Contamination by the presence of CO_2 in atmospheric air.

In order to reduce time lag, it was decided to contain the glass electrode in the smallest possible space, which increased the velocity of D_2O passing the glass electrode and reduced the effects of contamination.

The leakage rate of KCl from the salt bridge was minimized by the fitting of a low-porosity salt-bridge plug, and therefore contamination of the D_2O was reduced. The velocity of D_2O between the electrodes had to be increased to prevent back diffusion of KCl and contamination of the glass electrode. A small polythene capillary, leading off from the glass electrode chamber just above the neck of the glass electrode, was fitted to increase the velocity so that diffusion of KCl could not occur. The hopper was polythene lined, while the inlet and outlet connections and capillaries were made in heavy polythene. These, filled with low-conductivity D_2O, acted as high-resistance stoppers to leakage circuits. The use of an insulator for the capillary leading off from the glass electrode chamber introduced electrokinetic potentials which were produced across the capillary and, therefore, between the electrodes, due to the velocity of low-conductivity D_2O through it.



"Dall" tube for differential pressure flow measurements with low total pressure loss.

The bore of this capillary had, therefore, to be carefully chosen in order to achieve sufficient separation of KCl and not introduce serious electrokinetic potentials.

It was necessary to maintain the level of D_2O in the primary element at the height of the D_2O outlet. By providing a helium purge of approximately 1 bubble per minute the level of D_2O is maintained and atmospheric air excluded from the primary element. Excess helium was allowed to pass out of the primary element with the D_2O.

A standard electrometer and pH recorder were supplied, the latter being fitted with alarm contacts operating at both high and low pD values.

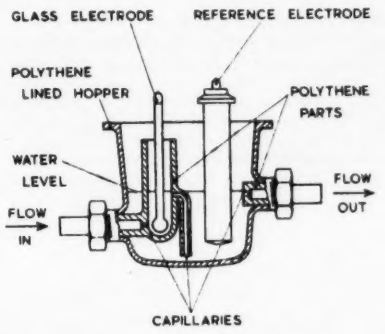
Reactor Helium Circuit

The helium circuits are complicated because of the operational flexibility provided. Helium can be taken from various points of the circuit and circulated either through

* "Some aspects of continuous pH measurement" by D. Brooks, R. S. Medlock and D. A. Rudd. A paper read before the Society of Instrument Technology at Swansea, September 1957.

a cooler, drier and adsorber unit (to remove unwanted gases) or through the catalytic recombination unit to recombine deuterium and oxygen resulting from the dissociation of D_2O. This is necessary as failure to purify and recombine deuterium and oxygen would allow an explosive mixture to accumulate in the reactor.

The flow through the drier/adsorber unit, and the flow through the combination unit, are each measured on in-line indicators. Bi-metallic temperature indicators measure at the inlet and outlet of the cooler, the outlet of the adsorber and both inlet and outlet of the recombination unit.



Special arrangement of pH sampling electrodes, to reduce D_2O contamination, and time-lag in measurements.

The tank gasholder maintains a constant pressure in the helium system during normal conditions. Provision is made for an appropriate expansion of the gas due to a temperature rise. Vessels are fitted for this purpose and protection is provided for the gasholder by two quick-closing valves connected in series. These valves are operated by pressure switches measuring the reactor helium pressure which also operate three-way valves in the air line to the quick-closing valves and, therefore, ensure automatic closure when the pressure rises to a predetermined value.

The normal pressure of the helium is only a few inches w.g., but the system is designed to accept an overload of 40 p.s.i.g. so that it would still function even in the event of a serious emergency. Pressure gauges either have to withstand the very great overload or means be provided for their protection. The differential pressure gauge measuring across the catalyst in the combination unit is designed to withstand the overload on either side. The pressure of helium in the reactor is measured by means of a pneumatic transmitter and is protected by a pressure switch operating a solenoid valve to close the pressure line to the transmitter in the event of excessive helium pressure rise. A gauge is installed which indicates the pressure at the outlet from the gasholder, while limit switches are provided on the gasholder for alarms at high and low level, and also to initiate a reactor trip at an extra-low level.

Reflector Helium Circuit

The graphite reflector is pressurized with helium at constant pressure from a gasholder, which is fitted with limit switches to operate alarms on high and low levels. A local pressure gauge indicates the pressure.

Cooling Tower Water Circuit

There are four main and two emergency pumps, as shown. Pressure gauges indicate discharge pressures with a common gauge for the suction. The total flow of water from the pumps is measured by a Dall tube and transmitter for indication on the main panel, and alarms are operated on low flow.

A trip is required on loss of flow of water to the cooling-tower nozzles. This function is provided by means of electrodes and relays operating on the level in the inlet header. The level in the cooling-tower basin is also controlled by electrodes and relays which include a trip for low level and an alarm for high or low level.

A bi-metallic temperature indicator measures at the H_2O outlet from the main heat exchangers, and operates an alarm at high temperature, while a similar indicator at the outlet of the cooling tower is fitted with alarm contacts for high and low temperatures. A recorder at the panel provides the temperature of the cooling water at the inlet header to the heat exchanger and alarms are operated at high or low temperatures.

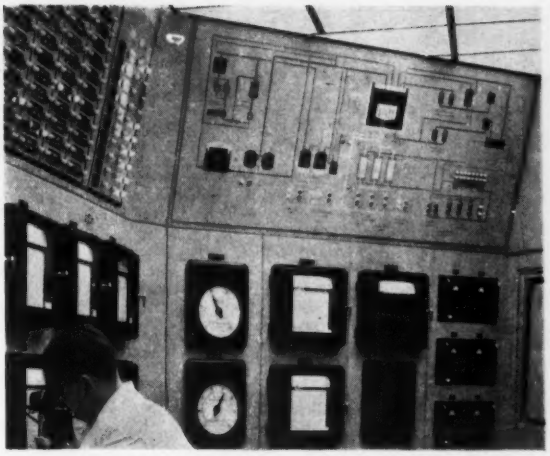


Photo: Atomic Energy Authority

Close-up of mimic diagram in control room. (A large reproduction of this diagram appears on the back of the pull-out, facing p. 151.)

Other Cooling-water Circuits

The shield water cooling and the fine control rod cooling have instrumentation similar to that described for the cooling tower water circuit. Instruments also measure the temperature and flow of the cooling water associated with experimental loops.

Fuel Element Temperatures

Two 12-point recorders in the main control room provide temperature readings of various fuel elements, while a high-speed recorder is used for the centre fuel element temperature measurement. The latter instrument can record the temperature of any of three fuel elements at the centre of the reactor. These instruments are provided with high-temperature alarm contacts. Amplifiers operate trip relays in the event of high temperature of one of the three centre fuel elements. Many thermocouples in the graphite reflector and concrete shield are connected via a manual selector switch to a temperature indicator on the main panel.

Acknowledgments

The author wishes to express his appreciation of the helpful discussions with Head Wrightson Processes Ltd. who, as main contractors, provided instrument specifications.

Pages 151 to 153

L'Instrumentation Physique du Pluto

Les mesures physiques principales requises dans un réacteur de ce genre sont celles de l'écoulement, de la différence de pression, du niveau, de la température, du pH, et de la conductivité, et l'instrumentation d'un réacteur d'études est normalement très poussée. Une certaine considération est accordée à la présentation de renseignements et à un certain nombre des détails de conception les plus essentiels, tels que l'importance des matériaux qui entrent en contact avec l'eau lourde, et les méthodes sévères d'essai adoptées. La mesure du pH du D_2O a présenté des problèmes spéciaux de contamination et le système mis au point utilise un soutirage très réduit (10–15 cm^3/h) qui est purifié avant d'être renvoyé au circuit principal.

On fait ressortir que l'instrumentation physique forme partie intégrale du système de contrôle et de sécurité du réacteur.

Die Ausrüstung mit physikalischen Instrumenten im Werk Pluto

Die hauptsächlichen physikalischen Messungen, die bei einem Reaktor dieser Art vorgenommen werden müssen, sind Fluss, Druckdifferenz, Flüssigkeitsstand, Temperatur, PH-Wert und elektrische Leitfähigkeit, und die Ausrüstung eines Reaktors für Forschungszwecke mit Instrumenten ist gewöhnlich sehr reichhaltig. Es wird dabei die beste Darstellung der Angaben in Betracht gezogen und es werden wichtigere Einzelheiten der Konstruktion, wie z.B. die Wichtigkeit der Materialien, die mit schwerem Wasser in Berührung kommen, berücksichtigt, und die genauesten Prüfmethoden angewendet. Die Messung des PH-Wertes von D_2O brachte spezielle Probleme der Verseuchung, und das System, das entwickelt wurde, arbeitet mit einer sehr kleinen Abzapfmenge (10–15 ccm/h), die vor der Rückleitung in den Hauptstrom gereinigt wird.

Es wird betont, dass die Ausrüstung mit physikalischen Instrumenten einen integralen Teil der Reaktor Regulierung und des Sicherheits Systems bildet.

La Instrumentación Física de Pluto

Las mediciones físicas principales que se necesitan en un reactor de este tipo son: flujo, diferencia de presión, nivel, temperatura, pH y conductividad, y la instrumentación de un reactor de investigaciones es generalmente complicada. Se presta consideración a la presentación de información y a algunos de los detalles más importantes de diseño, tales como la importancia de los materiales que hacen contacto con el agua pesada, y los estrictos métodos de ensayo empleados. La medición de pH del D_2O presentó problemas especiales de contaminación y el sistema evolucionado utiliza un sangrado muy pequeño (10–15 cc./h) el que se purifica antes de devolverlo al circuito principal.

Se hace hincapié en que la instrumentación física forma una parte integrante del control del reactor y del sistema de seguridad.

Pages 155 to 157

L'Instrumentation des Réacteurs d'Energie

La fonction de l'instrumentation d'un réacteur d'énergie de grandes dimensions est comparée avec celle qui est fournie normalement pour une centrale d'énergie traditionnelle, et avec celle d'un réacteur d'études.

On y dresse aussi un tableau typique de l'instrumentation, en se référant à des dessins indiquant les points de mesure important et le genre de caractéristique de contrôle incorporée, ainsi que l'emplacement et le groupement mêmes des instruments dans une salle de commande. Il y a une brève analyse des méthodes adoptées pour la mesure et le contrôle de l'énergie dans toute l'étendue de la centrale.

Die Ausrüstung eines Atom-Kraftwerkes mit Instrumenten

Der Zweck der Instrumente der verschiedenen Art in einem grossen Atom-Kraftwerk wird mit der normalen Ausrüstung des üblichen Kraftwerkes, ferner mit der Ausrüstung eines Reaktors für Forschungszwecke verglichen.

Eine typische Liste von Instrumenten für eine Anlage ist beigefügt, mit einem Plan, der die wichtigsten Punkte zeigt, wo Messungen gemacht werden, und ferner die Art der Kontroll-Vorrichtung, die eingebaut ist, zusammen mit der Anordnung und Gruppierung der Instrumente, wie sie in Wirklichkeit im Ueberwachungsraum ausgeführt ist. Eine kurze Analyse der Methoden, die zum Messen und Regulieren der Kraft an allen Stellen des Werkes angewendet werden, ist gleichfalls gegeben.

Instrumentos para un Reactor de Energia

El valor de los instrumentos necesarios para un reactor de energía grande se compara con los normalmente suministrados a una central de energía del tipo corriente y con los necesitados para un reactor de investigación.

Se incluye un plan típico de instrumentación relacionado con los diagramas que muestran los puntos importantes de medición y el tipo de dispositivo de control que se incorpora, juntamente con la verdadera agrupación y emplazamiento de los instrumentos en la sala de mandos. Se hace un breve análisis de los métodos adoptados para medir y controlar la energía en todas partes de la central.

Pages 158 to 162

Le Système de Détection des gaz pour Berkeley

Les systèmes de détection pour les bidons protecteurs de combustible ayant éclaté ont suivi jusqu'ici les mêmes principes de base que ceux qui sont appliqués à Calder Hall, bien qu'ils diffèrent en ce qui a trait à la manière de les approcher du point de vue construction. Dans cet article, on décrit l'appareillage conçu pour la nouvelle centrale de Berkeley. Des changements significatifs sont représentés par l'incorporation de valves à 4 groupes à actionnement manuel dans l'unité de valves rotatives automatiques. L'emploi d'un filtre de céramique tubulaire, la conception de précipitateur pour donner une plus grande facilité d'accès, et l'emploi d'un compresseur sans joints d'arbre étanches sont d'autres points intéressants. On prédit que les développements de l'avenir réduiront considérablement la quantité de tubulures et d'équipement requis.

Das Gas-Ueberwachungssystem im Werk Berkeley

Die Systeme zur Ueberwachung von Brennstoff Elementen und zur Meldung von geborstenen Hülsen sind bisher nach denselben Grund-Prinzipien angelegt worden, nach denen die Calder Hall Anlagen vorgesehen waren, wenn sie auch in der tatsächlichen technischen Ausführung Verschiedenheiten aufweisen. In dem vorliegenden Aufsatz wird die Anlage, die für das neue Werk Berkeley entworfen worden ist, beschrieben. Zu den wesentlichen Aenderungen gehört die Einfügung der von Hand bedienten Vier-Gruppen-Ventilen in den automatischen Block mit rotierendem Ventil. Die Verwendung eines rohrförmigen keramischen Filters, die Konstruktion der Fällanlage mit dem Ziel besserer Zugänglichkeit und die Verwendung eines Kompressors ohne Wellenpackungen sind weitere interessante Punkte. Es wird angenommen, dass die zukünftige Entwicklung die Grösse der Rohranlagen und der sonst erforderlichen Ausrüstung erheblich reduzieren wird.

El Sistema Monitor de Gases para Berkeley

Los sistemas monitores para los bidones protectores reventados de combustible han seguido hasta la fecha los mismos principios básicos que los que se aplican en Calder Hall, aunque difieren por el lado de su técnica efectiva. En este artículo se describe el equipo diseñado para la nueva central de Berkeley. Los cambios importantes consisten en la incorporación de las válvulas de 4 grupos manualmente operadas en la unidad de válvulas rotativa y automática. El empleo de un filtro cerámico tubular, el diseño de la unidad de precipitación para ofrecer mayor accesibilidad, y el uso de un compresor sin sellados herméticos de eje son otros puntos interesantes. Se pronostica que futuras mejoras reducirán considerablemente la cantidad necesaria de tubería y equipo.

Power Reactor Instrumentation

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An evaluation of the instrumentation needs of power stations, compared with research reactors, together with a short discussion on the overall control of electrical, steam and reactor sections for station loading. A schedule shows the important measuring points and the physical location of the instruments.

BROADLY speaking, the function of instrumentation in a nuclear-reactor power plant is the same as in more conventional power stations:—

(i) To present an accurate and easily interpreted picture of heat/power transmission throughout the plant from furnace to bus-bars, showing the state of all sections of the plant under shut-down, start-up, and power operation.

(ii) To enable smooth and rapid adjustment of operating conditions, guarding against incorrect operational sequences.

(iii) To detect and display any departure from normal operating conditions in any section of the plant and the primary cause of the abnormality (e.g., pump failure), giving sufficient information to enable effective and safe correcting action—which may be automatic (including trips of all kinds), semi-automatic or manual—to be taken.

(iv) To enable maintenance (including maintenance on instruments) to be performed and units of plant to be restored to operation with the minimum of disturbance and maximum of safety to plant and personnel.

(v) To provide time records and check readings of various parameters for operating, statistical and investigational purposes.

There are, however, differences both in kind and in scale of the instrumentation in a station using nuclear steam-raising. These differences may be enumerated as follows:—

(i) The necessity for radioactivity monitoring, notably of the site and surroundings, the effluent, selected working areas, personnel, and the primary coolant circuit.

(ii) The measurement of neutron flux.

(iii) The multiplicity of steam-raising-unit instrumentation, due to the use of several steam-raising units.

(iv) The extensive nature of the commissioning and check instrumentation[1] (though the scale of this will be reduced in subsequent stations of virtually the same design).

(v) The unavoidably arduous conditions of operation of some of the measuring devices.

(vi) The necessity for special protective instrumentation of an automatic nature, which must be extremely reliable, in view of the vulnerability of the plant to long-term damage by fission-product contamination.

(vii) The necessity to provide a first line of defence against faults, that will take automatic corrective action without tripping the reactor, in view of the heavy cost of losing large units of generating capacity for the period of time involved in restoring a tripped reactor to operation.

(viii) The complexity of instrumentation and control equipment required for the continuous processes of on-load fuel handling and refuelling.

Comparison with Research Reactor

Compared with a research reactor operated as an irradiation facility, there are differences in instrumentation both of emphasis and of scale in the case of a power reactor:—

(i) Although the measurement of neutron flux is important in both types of reactor, greater accuracy is likely to be required in a research reactor, and measurement of gamma flux may also be necessary.

(ii) The significance of the neutron-flux measurement in a power-producing reactor[2] arises through (a) lack of any other indication of the state of the fission process at low power levels, particularly in the neighbourhood of criticality; (b) the fact that neutron flux is the parameter responding most rapidly to a reactivity change; (c) the fact that balance of flux and coolant flow is fundamental in establishing desired temperature conditions.

The utility of neutron-flux instrumentation at normal levels of operation nevertheless relies on frequent calibration against thermal-power measurement. Although the steady-state heat-generating contribution of fission-product decay activity (about 6%) can be allowed for in the calibration of the neutron-flux instrumentation, significant changes in power level result in transients that render the correction invalid. Furthermore, movement of control rods affects the flux pattern and hence the accuracy of the measurement.[3] It should be noted that after a power change, movement of control rods to correct for xenon-poison transients is necessary for a period of many hours. Measurement of core flux distribution is necessary to confirm fuel-changing programmes.

(iii) Response of trip devices—particularly of the reactor "period" measuring system—will probably require to be quicker in a research reactor because: (a) the reactor is frequently shut down and started up; (b) the existence of experimental "loops" and removable absorbers increases the risk of reactivity addition, especially when shut down; (c) the built-in excess reactivity is likely to be high.

(iv) High-flux research reactors may require the provision of computers[4] for estimating xenon override.

(v) Temperature measurement within the core—and structure—is more vital in a power-producing reactor.

(vi) Heat production, heat transmission, and efficiency of operation, in a research reactor are of secondary importance, and there is correspondingly less instrumentation covering this aspect.

(vii) Automatic control in a research reactor is required to maintain constant flux in the operating condition, and may also be designed to facilitate start-up.[5]

(viii) Owing to the necessarily frequent shut-downs of research reactors, there may be more opportunity for access to instruments for testing and maintenance. Furthermore, the instrumentation associated with on-load fuel handling is avoided. In the case of a power reactor, on the other hand, maintenance has normally to be done with the reactor operating. As an example consider the replacement of a faulty neutron-flux detector. If these are situated outside the pressurized circuit the problem is one of substituting a new chamber and satisfactorily disposing of the faulty one without exposing personnel to irradiation from activity

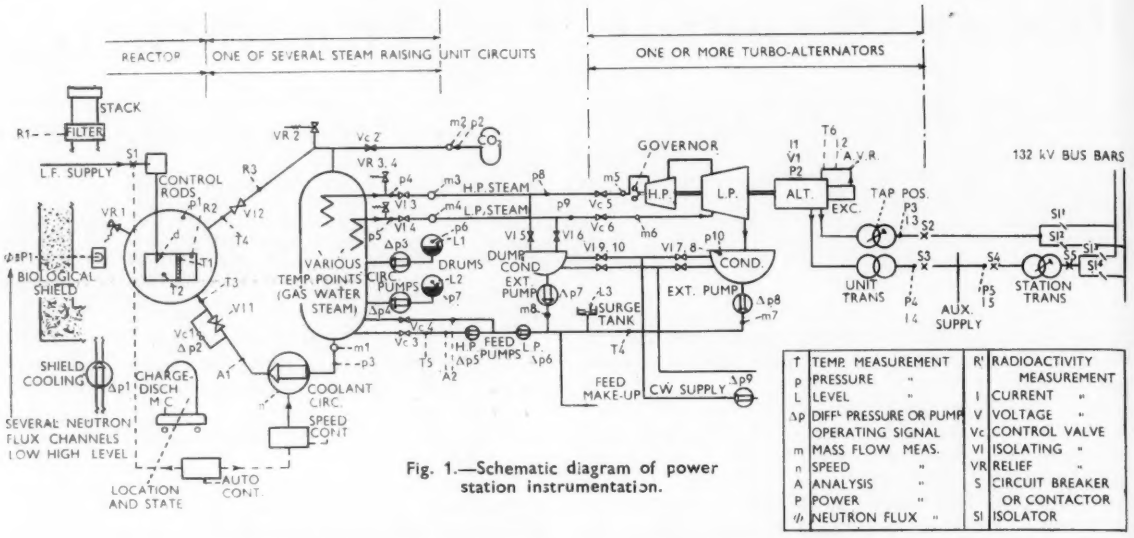


Fig. 1.—Schematic diagram of power station instrumentation.

t	TEMP. MEASUREMENT	R'	RADIOACTIVITY MEASUREMENT
p	PRESSURE "	I	CURRENT "
L	LEVEL "	V	VOLTAGE "
Δp	DIFF^L PRESSURE OR PUMP OPERATING SIGNAL	Vc	CONTROL VALVE
m	MASS FLOW MEAS.	VI	ISOLATING "
n	SPEED "	VR	RELIEF "
A	ANALYSIS "	S	CIRCUIT BREAKER OR CONTACTOR
P	POWER "	SI	ISOLATOR
φ	NEUTRON FLUX "		

SCHEDULE OF CENTRAL CONTROL ROOM INSTRUMENTATION

Type of instrumentation	Symbol on Fig. 1	Location on Fig. 2
Reactor		
Total mass flow of coolant (IR). Hand/auto control of coolant flow (C)	Σm1	3
Grouped circulator speed control (C)	—	3
Hot- and cold-duct coolant temperatures (IR)	T4av. T3av.	3
Power-setting unit for auto-control	—	3
Low-level neutron power (IR) (for use with pulse-counting channel)	Φ	9
Log. neutron power (IR)	Φ	9
Moderator temperature multi-point (IR)	T2	9
Fuel-element temperature (single point and multi-point) (IR)	T1	3 and 9
Various alarm annunciations	—	9
Pre-selection keys for auto-transfer of two circulators to battery following complete supply failure (CI)	—	9
Reactor ventilation system (CI)	Δp1	9
Sweep-second synchronous clock (for period measurements)	—	9
Coolant pressure in reactor (IR)	p.1	9
High-level neutron power (linear IR) (two ranges)	Φ	3
Retraction control for low-level chamber (CI)	—	3
Log. neutron power (I)	Φ	3
Low-level neutron power (I) (pulse counting)	Φ	3
Period-meter (I)	Φ	3
Trip-margin indicator (switched to any of three shut-down amplifiers) (I)	Φ	3
Drift power (IR)	Φ	3
Neutron - flux / coolant - flow ratio (IR)	Φ/Σm1	3
Reactor thermal-power output (IR)	Σm1 (T4–T3)	3
Trim-flux/flow ratio, for use with auto-control (C)	—	3
Control-rod speed group selection (C)	—	3
Control-rod movement (C) (one per group)	—	3
Control-rod position (I) (one per group)	d av.	3
Control-rod position (R) (one per group)	d av.	S
Desired power (I), for use with auto-control	—	3
Fission-product detection (CIR)	R2, 3	S
Individual control-rod position (I) and alarms	d	S
Fuel-handling reactor-plan position diagram (I)	—	S
Safety equipment:		
(a) Trip indication and test	—	6
(b) Intermediate equipment e.g., shut-down amplifiers	—	S.E.R.

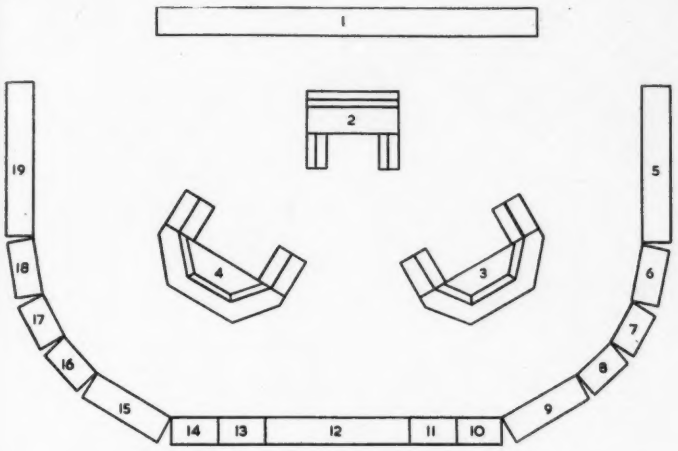
Type of instrumentation	Symbol on Fig. 1	Location on Fig. 2
Coolant Circuits *(for each circuit)*		
Switched differential pressure across cold duct main valve (I)	Δp2	7, 8, 10, 11
Control of cold-duct valve and by-pass (CI)	VI1 Vc1	7, 8, 10, 11
Controls for circulator drive, including single or grouped operation switch (CI) and speed indication	n	7, 8, 10, 11
Coolant flow (IR) and range switch	m1	7, 8, 10, 11
Coolant pressure (I)	p3	7, 8, 10, 11
Temperature push-buttons for selection of various coolant temperatures	—	7, 8, 10, 11
Control of hot-duct valve (CI)	VI2	7, 8, 10, 11
Control of coolant make up (C)	Vc2	7, 8, 10, 11
Temperature of coolant in cold and hot ducts (double movement I)	T3, 4	7, 8, 10, 11
Various fault annunciations (I)	—	7, 8, 10, 11
Moisture in coolant (IR)	A1	S
Steam-raising Units (Note that feed-water supply is automatically controlled from drum-level and steam-flow measurements via Vc3, 4) *For each S.R.U.*		
Feed-water regulator isolation-valve control (H.P. and L.P.) (CI)	—	7, 8, 10, 11
Feed-water by-pass control and indication (H.P. and L.P.) (CI)	—	7, 8, 10, 11
Various temperature-selection buttons and shared temperature indicator (I)	—	7, 8, 10, 11
Drum pressure (H.P. and L.P.) (I)	p6, 7	7, 8, 10, 11
Boiler circulating pumps (H.P. and L.P.) (CI)	Δp3, 4	7, 8, 10, 11
Drum-level indicator (H.P. and L.P.) (I)	L1, 2	7, 8, 10, 11
Steam flow (H.P. and L.P.) (I)	m3, 4	7, 8, 10, 11
Superheater stop valves (CI)	VI3, 4	
Superheater by-pass and drain valves (CI)	—	7, 8, 10, 11
Steam flow (R)	m3, 4	S
Turbines, Dump Condenser and Feed System		
Control of throttling valves (H.P. and L.P.) involving use of speeder gear and setting of pressure governors (C)	Vc5, 6	3 and 2
H.P. and L.P. steam pressures at receivers (I)	p8, p9	9
H.P. and L.P. steam flow (I) and condensate flow (I)	m5, 6, 7	12
Surge-tank and reserve-tank levels (I)	L3	12
Emergency steam trip button	—	12
Turbine-fault annunciation (I)	—	12

Type of instrumentation	Symbol on Fig. 1	Location on Fig. 2
Extraction-pump functioning (I)	Δp8	12
Feed-pump current (H.P. and L.P.) (I)	Δp5, 6	12
Stand-by d.c. pumps operating (I)	—	12
Dump condenser and extraction pump operating (I)	Δp7	12
Condenser vacuum (I)	p10	12
Feed-water temperature (I)	T5	12
C.W. pumps operating (I)	Δp9	12
C.W. pumps control (C)	—	12
Dump-condenser control (auto-sequence) (C)	—	3
Alternators and Transformers		
Individual exported MW (I) and MVAR (I)	P3	1
Individual exported MWh (I)	—	MP
Individual stator volts and current (I)	I1, V1	1
Individual generated MW (I)	P2	3
Current at 132 kV (I)	I3	1
Protection	—	R.P.
Transformer tap (C)	—	2
Transformer tap (I)	—	1
Rotor current (I)	I2	1
Rotor temperature (I)	T6	1
Rotor phase angle (I)	—	1
Excitation control (including A.V.R.) (CI)	—	2
Synchronizing connections and instrumentation (CI)	—	1
Emergency Supplies *(Battery and Diesel)*		
Annunciation	—	2
Station and Unit Transformers		
MW and MVAR per incomer (I)	P4, P5	1
Current per incomer and coupler (I)	I4, I5	1
MWh per incomer (station transformers) (I and R)	—	M.P.
O.C.B. position (CI)	S3, S4	1
Synchronizing voltmeter and synchroscope (I)	—	1
Transformer Tap (CI)	—	2, 1
Busbars		
Total MW export (I)	—	2
Total MVAR export (I)	—	2
Instructed MW and MVAR export (I)	—	2
Position of main isolators and C.B.s (CI)	SI1—SI4, S2, S5	1
Standard-time and frequency-time clock (R)	—	1
Total MWh export (R)	—	MP

Symbol.—C=Control. I=Indication. R=Recording.

Locat o n symbols (Col. 3).—S=Subsidiary panel. S.E.R.=Safety Equipment Room. M.P.=Metering Panel. R.P.=Relay Panel.

Note.—*Tnese pane.s are not shown on Fig. 2.*



KEY

1 Alternator, switchyard and H.V. auxiliary supply panel.
2 Electrical operator's desk.
3 Reactor 'A' operator's desk.
4 Reactor 'B' operator's desk.
5 Plan position display for fuel (A) handling and control rod position.
6 Trip indication and test panel. (A)
7 Heat exchanger instruments and controls. (A)
8 Heat exchanger instruments and controls. (A)
9 Additional reactor instrumentation. (A)
10 Heat exchanger instruments and controls. (A
11 Heat exchanger instruments and controls. (A)
12 Turbine, feed water and dump condenser panel. (A, B)
13 Heat exchanger instruments and controls. (B)
14 Heat exchanger instruments and controls. (B)
15 Additional reactor instrumentation. (B)
16 Heat exchanger instruments and controls. (B)
17 Heat exchanger instruments and controls. (B)
18 Trip indication and test panel. (B)
19 Plan position display for fuel handling and control-rod position. (B

Fig. 2.—Block plan showing layout of power station control panels.

in the chamber, or neutrons and gamma-rays streaming from the chamber cavity. Broadly, two schemes may be adopted. The first involves the provision of sufficient spare measuring cavities to enable the faulty chamber to be withdrawn from the thermal column into a biological shield where it can be left to "cool" until handling becomes possible, and until the reactor is shut down for some other reason. The alternative is to provide some form of rotatable shield which eliminates streaming problems and may also provide mortuary location for the faulty chamber.

(ix) Fission-product detection is generally of greater importance in a power-producing reactor and is of necessity on a much larger scale, forming a major proportion of the total cost of instrumentation and control.

Typical Instrumentation Schedule

Fig. 1 shows a flow diagram of a typical nuclear power station, with the important measuring points and control features incorporated. These, and others displayed in the central control room, are scheduled and some indication given of location of the control and display features (for reactor A only) on the panels shown in Fig. 2. The electrical instrumentation generally follows standard practice, but is quoted for completeness.

Overall Power Measurement and Control (references are to Figs. 1 and 2).

Dispatch of instructed MW and MVAR will normally be under the control of the electrical operator (2) in the central control room. MW generation is controlled by the steam input to the turbines, assuming constant exhaust conditions. Such control is exercised through valves Vc5 and Vc6.

Turbines are required to be provided with some form of automatic regulation of input steam. The controlling signal may be either steam pressure or turbine speed (which is equivalent to the system frequency when the sets are on load), adjustment of setting being available to the reactor operator (3) in a nuclear power station.

In the case of pressure governing, the throttling valves are automatically controlled (e.g., via an Askania-type controller) to maintain steam pressures up-stream of the valve which droop slightly with falling load, the droop being necessary for stable operation. The effect of this arrangement is that the turbines are insensitive to changes in system frequency, and deliver the power that is produced by the reactor and transmitted through the plant. The pressure governors are overridden by the speed governor for purposes of running up and synchronizing, and in the event of an excessive rise in speed.

To change power in such circumstances the reactor operator will make an adjustment to the power produced by the reactor. Such an adjustment must involve both neutron flux (Φ) and coolant flow (Σm1) if temperatures in the coolant circuit (T3, T4) are to be kept reasonably constant. These may be adjusted separately by movement of control rods (d) and alteration in speed of circulators (n), but there is some advantage in linking the two so that the reactor power is made to follow the change in coolant flow under the action of a closed-loop system. Such a closed-loop system serves to stabilize neutron flux and maintain a suitable flux/flow ratio in the event of partial flow failure. The relationship between flux and flow can then be trimmed or made to follow a predetermined characteristic dependent on power level. Automatic control based on a temperature signal (T4) is a possible alternative.

In the case of speed governing of the turbines, which is the system adopted on conventional power stations, a fall in the system frequency due to a rising load will cause the speed governor to open the L.P. and H.P. throttling valves (which can be coupled to preserve a suitable L.P./H.P. steam flow ratio). As a result of this increased steam flow there will be a depression in steam pressures and in evaporating temperatures, accompanied by a release of heat from the stored thermal energy of the steam-raising units. The lower coolant temperature (T3) will then fall, and reactor temperature coefficients will produce a modification in reactivity and hence a change in power. The inherent change may not result in satisfactory conditions in the coolant circuit and it is desirable to regulate the reactor externally. Such external control may conceivably be exercised by the reactor operator, preferably with the assistance of the automatic feature already described, or the control may be made completely automatic by driving the reactor-power-setting device by a signal derived from the change in steam pressures, in such a manner as to reduce the pressure error.

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(*For translations see page* 154)

Gas Monitoring Equipment For Berkeley Power Station

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This article reviews the changes in design of burst slug or burst can detection equipment that have taken place since Calder Hall and forecasts future developments.

IN the present state of fuel-element technology, no nuclear power programme based on graphite-moderated gas-cooled reactors could be conceived without a sensitive and reliable system of detecting faulty fuel elements. The C.E.G.B. nuclear power stations are developed from Calder Hall and the burst cartridge detection equipment for them is still basically similar to that described by Long[1] and his associates. What changes have been made are by no means a fundamental re-appraisal but are rather in the nature of an engineering revision. The Dowty equipment for Berkeley is only one solution to the engineering problems involved; most of the problems, however, are common to all systems.

Principles

The detection of faulty fuel elements depends on the identification of fission product activity in the coolant. Thermal neutron fission of U^{235} gives the well-known saddle-shaped mass yield curve[2] with rather flat maxima about mass numbers 95 and 139. The newly formed fission fragments are radioactive, the normal decay process being by β emission. In some decay schemes the new nucleus is not necessarily at its ground level and excess energy is removed by the emission of hard gamma radiation. When the excitation is greater than the binding energy delayed neutron emission can also occur. The decay of Br^{87} illustrates all three processes.

Despite their low yield delayed neutrons are important in reactor control, and can be used[3] to detect faulty fuel elements. The counting statistics tend to be poor, however, and for carbon dioxide cooled reactors sensitivity is reduced by the presence in the coolant of non-fission product N^{17} ($O^{17}(np)N^{17}$) which is also a delayed neutron emitter. Direct beta or gamma monitoring of the coolant is similarly limited by gaseous non-fission product activities, in this case N^{16}, O^{19} and A^{41}. However, these gases do not give rise to solid radioactive daughter products, and electrostatic precipitation provides a means of discriminating against them. Emission of a beta particle leaves the atom with a net positive charge so that if a sample of gas from one of the fuel channels is allowed to decay, the radioactive daughter products of the fission product gases krypton and xenon can be collected using electrostatic precipitation.

Particulate matter should first be removed by filtration; subsequent beta monitoring of the collector can then give an unambiguous indication of fission product activity due only to the daughter products of krypton and xenon, which both lie on the maxima of the fission yield curve, and adequate sensitivity can be obtained with small gas samples. The C.E.G.B. reactors employ closed-circuit cooling, but as the more important isotopes of krypton and xenon have short half-lives of seconds or, at most, minutes, build-up of gaseous activity is not serious. All the channels would be affected by such a build-up and the sensitivity of detection of individual fuel element failures would be much reduced.

At Calder Hall, and so far at all stations of this type, one sampling pipe from each channel is taken through the reactor pressure vessel. Continuous monitoring of each and every channel is normally unnecessary and, as there are several thousand channels per reactor, would be prohibitively expensive. The basic units, therefore, are selector valves, filters, precipitator and counter units, and compressors to return the samples to the main gas circuits.

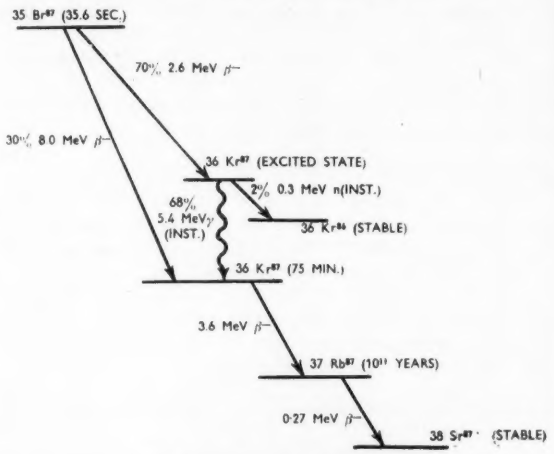


Fig. 1.—Decay chain of Br^{87}.

Channel Selection

The frequency of sampling of any given fuel channel is determined by the probable time taken for a failure to develop from being just detectable to a dangerously high level of activity. This, of course, depends on the sensitivity of detection, which is limited ultimately by uranium contamination of the surface of the canning material. With the levels of surface contamination now obtained, it is better to scan relatively frequently and group several channels together for monitoring. When a failure has been detected in a group it is traced to a particular channel by individual monitoring, and its development can then be followed.

Various sampling methods which will meet these requirements are possible. Berkeley follows Calder Hall practice, in which channels are normally grouped in fours, using manual cocks, and groups of four are selected in sequence using automatic rotary valves. An important difference is that the cocks are no longer separate, but are formed in a

stainless-steel forged ring which constitutes part of the rotary valve body. The pipes from the reactor can be taken direct to the rotary valve assembly with considerable savings in space, complexity, and installation problems on site. In operation the four samples are normally combined and passed to one port of the valve. Alternatively, any one sample may be by-passed for individual monitoring, while the remaining three are combined and sampled as usual. In a sixth position all ports are closed to permit maintenance work on the valve.

The principal feature of the design is that the shut-off facility is provided by metal discs spring-loaded against each other, mating faces being hardened and lapped optically flat to prevent leakage into, and between, the ports in the discs. This construction gives a very reliable seal with negligible leakage. One disc is fixed in the bottom of the bore in the forged ring, while the other spigots onto

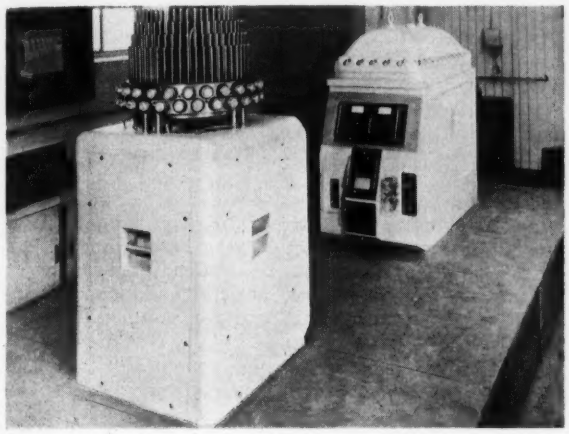


Fig. 2.—Prototypes of the valve and precipitator units to be installed at Berkeley. (More recent designs of precipitator unit provide for housing in cabinets occupying the same floor space as is now taken by the valve alone.)

the end of the cock insert, which is of roughly cylindrical form, with four radial annular bosses. In the normal position, gas from all four inlet pipes flows freely around the bosses and is passed through the disc seal to a port in the rotary valve. On rotating the insert the bosses align in turn with their corresponding pipe inlet, and connect with an axial hole through which the gas sample can be passed for continuous monitoring, the remaining pipe inlets being unimpeded.

The small clearances necessary between the boss and the bore of the cock do not allow of perfect sealing, but this is not necessary provided that the dilution is small. The disc seal closes the axial continuous sampling port in both the normal and the shut-off positions and this provides a near-perfect seal. Dilution of the individual sample then, is by its three immediate neighbours only, and is at an acceptably low level.

Rotation is effected by means of a spindle which comes out through a shaft seal, and a screw-on cap over the end of the spindle further reduces the possibility of gas leakage to atmosphere. The insert and the rotating disc are both hard chrome-plated which gives excellent anti-galling surfaces against the stainless steel of the forged ring and the fixed disc. Corrosion fretting properties are also good.

The outlets from the manual cocks terminate in ports in a flat steel disc mounted underneath the forging, the underface of this disc being hard chrome-plated and ground and

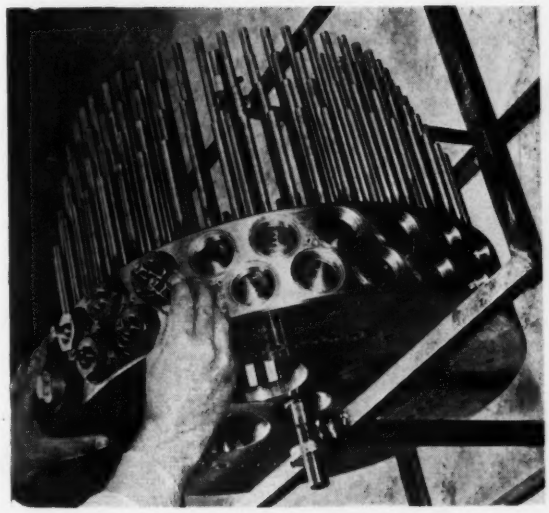


Fig. 3.—Close-up view of valve unit.

lapped to give a smooth surface for the annular carbon bush of the hollow scanning arm. The bush is spring-loaded against the desired port, the remaining ports being open to the bowl of the valve. The arm is mounted radially on a rotating shaft and gas is led away for monitoring through a drilling in the shaft, which is similarly terminated in a spring-loaded carbon bush. The intermittent drive mechanism is external to the gas circuit and the solid lower end of the shaft passes through double carbon face seals. The space between the seals is connected to stack via a restrictor, so any appreciable leakage is accompanied by build-up of pressure in the interspace. If the pressure exceeds a predetermined level, a pressure switch is operated, sounding an alarm.

Unlike the cocks, maintenance is possible on the valve but, while any valve is out of action, there is no means of monitoring the 200-odd channels affected. For this reason, the valve must also be exceptionally reliable, and the decision to use carbon-face seals was taken only after considerable experimental work had been carried out. The non-lubricating properties of graphite in the absence of condensable vapours are now notorious[4] and excessive abrasion of the carbon was anticipated. However, accelerated life tests carried out in dry carbon dioxide have shown that this will not be the case and, at Calder Hall where similar seals are extensively used, no serious troubles have been reported. While the physical processes are only imperfectly understood, it has been suggested that amorphous carbon is less dependent than the crystalline forms on the presence of adsorbed vapours. Alternatively, the carbon dioxide may be acting as a lubricant.

The intermittent drive is obtained from springs acting through a pawl on a ratchet wheel, rotating one tooth at a time. The springs are loaded by a single lobe cam with a slow rise, occupying most of the sampling time, and a rapid fall which allows the springs to rotate the ratchet wheel. As the rising cam slowly compresses the springs again the pawl gathers another tooth.

The springs are pre-loaded, so the motor is working under virtually constant torque conditions over most of the cycle. This permits the use of a much smaller motor than if all the work was done in the 1 or 2 seconds occupied by the drive. The reversal of torque, obtaining when the ratchet wheel and drive shaft of the valve rotate, is much

attenuated by frictional losses in the gearing. It is, in any case, less serious than the mechanical and electrical stresses imparted to the windings by the current surges associated with stopping and starting. No brake is required and a further advantage is that the springs limit the torque which can be applied to the shaft drive. If frictional losses in the valve become too great, the motor is still free to rotate. The position of the valve is indicated electrically and an alarm is given if the valve goes out of step.

As the intermittent drive mechanism is external to the gas circuits conventional oil-splash lubrication is used, and no lubrication problems should arise. The journal bearings on the shaft inside the pressure vessel of the rotary valve, however, can only employ solid lubrication. In applications of this type it is now common to use sleeve bearings of nylon or phenolic-based materials. In dry conditions, these are reasonably stable but, unfortunately, they must also operate during the commissioning of the reactor, when large quantities of water will be precipitated in the B.C.D. equipment. P.T.F.E. has an exceptionally low coefficient of friction and, when impregnated into sintered bronze, its poor creep properties are no longer important. However, bronze is incompatible with the fuel element canning material so this bearing cannot be used either. Various types of bearing have been subjected to accelerated life tests and, in general, satisfactory results have been obtained. Experimental work is being continued and, at present, the preferred bearing material is asbestos-loaded P.T.F.E., with carbon a good second.

The Filter

The cooling gases will normally carry a burden of dust particles which may be radioactive, either in their own right, or by virtue of fission product atoms adhering to them. The decay of N^{17}, O^{19} and A^{41} atoms, also present in the gas stream, causes considerable ionization, and the dust particles may be expected to acquire a charge by collection of ions, by their own beta decay or by frictional charging. If charged particles are present in the precipitator unit, they will be collected as in any electrostatic dust precipitator, and spurious counts may result. It is necessary, therefore, to interpose a filter before the precipitator unit.

At Berkeley, the filter is in the pipe ducting between the selector valve and the precipitator. A tubular ceramic filter will be used, which may be expected to remove particles down to 2 μ. The filter element is clamped between rubber rings, in a stainless-steel carrier which, with the filter inside it, is designed to be readily removable for filter renewal. The filter is closed at one end and the gas flows in through the open end. Particulate matter will be trapped within the bore and a cap is provided, which closes the carrier at the open end of the filter to prevent the escape of active material when a filter is changed.

Precipitator and Counter Unit

This consists of a wire precipitator and scintillation counter, again basically of the Calder Hall type, gas entering a cylindrical precipitation chamber radially, and leaving diametrically opposite. The collector is an axial wire and a strong electric field is maintained between the wire and the casing of the chamber. Solid atoms, formed by the decay of krypton and xenon, are deposited on the wire and, at the end of the sampling period, this portion of the wire is snatched into the scintillation counter for assay. The counter is shielded from external radiation by a cast-iron shielding block.

The wire is continuous and, as there is inevitably some build-up of activity, an adequate wire store must be provided to keep this small. It is calculated that the 70-ft store of the Berkeley equipment will give a wire memory of about 3% after a few days of operation. Build-up is then virtually complete.

The most obvious change in the precipitator units is the splitting of the pressure vessel at its greatest periphery, rather like a turbine casing, this design being adopted to give greater accessibility and ease of maintenance. Although fabrication is normally to be preferred for pressure vessels, this design with its open form and uniform sections lends itself to casting techniques. No porosity was observed in the raw casting of the prototype unit, and none is anticipated on the production equipment. Cast steel has been used in preference to cast-iron because of its superior tensile properties.

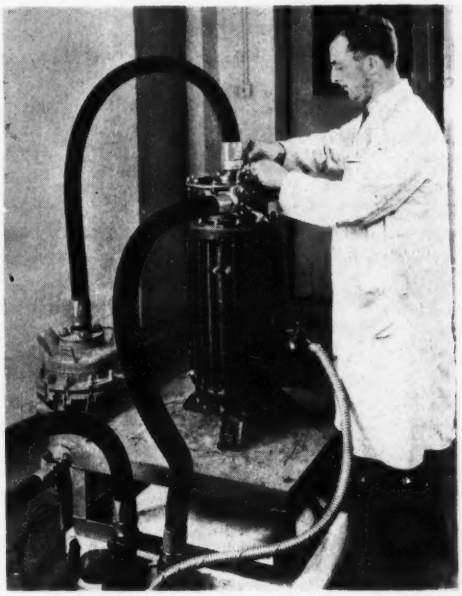
All components are mounted from the base and, as far as is practicable, are designed to be removed and replaced as complete sub-units. In particular, a fresh wire can be inserted as a continuous loop, without the necessity for threading and joining in situ. This is, of course, very convenient but—even more important—a properly spliced joint can be used, and this has made for greatly increased wire life, to be measured in years rather than weeks. Other methods of joining tend to give a large and abrupt change of stiffness at the joint and, with repeated flexing the loops fail due to fatigue, after a comparatively short time. A small advantage which has also accrued is that it has been possible to replace the pulley store by drums, which are simpler and give a more positive drive. Bearing problems are essentially the same as in the valve and the intermittent drive is also similar in general conception. A much greater angular movement is required, however, and the snatch box employs a six-tooth ratchet and the shafting is driven through 4-to-1 step-up gearing.

The design of the precipitation chamber is essentially a compromise between conflicting requirements. The number of ions available for collection depends on the time spent by the gas sample in passing through the chamber and, therefore, on the size of the chamber. Because of the mixing of incoming gas with that already in the chamber it is not possible to flush completely, and the chamber has a definite memory. Very approximately, the fission product count for a particular channel is proportional to the delay time of the chamber; for the memory count, a square law is more appropriate. With large chambers difficulty is also experienced in collection of the ions, because of the comparatively small collecting fields in the greater part of the chamber. Not only will some ions be swept out of the chamber but the charge on others will be removed be recombination, and neutral atoms will not be collected. The collection efficiency will be a function of the ratio of ion drift velocity in the collecting field to gas stream velocity; so high pressures and flow rates both militate against efficient collection.

Some amelioration can be obtained by careful design of the inlet and outlet ports, to prevent gas streaming. As an example, a chamber with plain pipe inlet and outlet gave a count of 1220, while the same chamber modified to include gauze spoilers and ventural widening of the inlet and outlet ports gave 1775 for the same nominal conditions. Rather surprisingly, the memory of the chamber was little affected, the respective figures being 17% and 18.5%. Calculations of the memory must assume some arbitrary figure for the turbulence. The maximum memory is obtained with 100% turbulence, and the calculated memory is then about 20%.

The scintillation counter consists essentially of a cylindrical phosphor sealed into a light-guide which couples it to an end-window photomultiplier tube. The light-guide also acts as a pressure window. For overall efficiency the scintillation counter should be designed for use with a

Fig. 4.—A B.C.D. gas bearing centrifugal compressor in a test cell.



particular chamber. When the boundary conditions are optimized considerable focusing of the ions towards the middle section of wire can be obtained. It has been found experimentally that, for a cylindrical chamber with an axial length equal to its radius, nearly all the ions collected are deposited on half the length of the collecting wire. Unless wire positioning is uncertain, the phosphor need be little, if any, longer, with consequent improvement in discrimination against A^{41} and gamma background.

As compared with other factors affecting the performance, work on scintillation counter efficiency is relatively straightforward and, when other experimental facilities were still lacking, it was possible to devote considerable effort to developing the design. A reasonable counting plateau was obtained and, as a consequence the beta sensitivity is largely independent of changes in temperature, amplifier gain or multiplier H.T. A marked improvement in the beta/gamma discrimination has been achieved without any loss of beta counts by reducing the phosphor thickness to about $\frac{1}{16}$ in. Scintillations in the light-guide limit the potentialities of further exploitation of this technique.

Accurate centring of the wire can be carried out, and the joint in the wire is no longer bulky. The hole through the phosphor, therefore, is of smaller bore than Calder practice permits, which again gives reduced sensitivity to gamma rays and also to the A^{41} content of the coolant gas. A clean carbon dioxide purge of the phosphor further minimizes the effects of A^{41} contamination.

The precipitator unit is mounted horizontally on a stand, which carries also the associated electronics and alarm circuits. As far as possible, all factors which will reduce sensitivity are monitored, alarm being given for low gas pressure, high gas temperature, low gas flow, precipitator H.T. failure, broken wire, and no wire snatch. The interspaces between the two carbon face seals of the drive and the double "O" rings on the main flange are also monitored.

The presentation and display of information given by the detector is a study in its own right and has been dealt with very adequately by Bowen[5] in a recent paper.

Fig. 5.—An experimental precipitator under test at pressure using the fission gas generator.

Compressor

Gas from the precipitator must be returned to the main coolant circuits using a compressor to make up the pressure drops in the system. The specification laid down by Long for the compressor was that:

(i) It must be reliable.

(ii) There must be no possibility of contaminating the carbon dioxide with lubricating oil.

(iii) Leakage of carbon dioxide must be as low as possible.

The compressors chosen for Calder Hall were of the carbon-ring reciprocating type and, although it was thought that the carbon rings were a potential weakness, they have been comparatively trouble-free. Carbon-ring compressors, however, are bulky and require, as auxiliary equipment, gas reservoirs and pressure-control valves, and some leakage is inevitable. They cannot, therefore, be regarded as ideal and Dowty have followed up a suggestion that gas-bearing compressors as developed at Harwell[6] should be a much more attractive proposition. While the principle is not new, the engineering application in this country has been pioneered by the U.K.A.E.A. and the bearings of the Dowty compressors follow A.E.R.E. designs.

Plain journal bearings are used, chosen to give good anti-galling properties on start-up. In the prototype, a chromium-plated steel shaft runs in a "meehanite" cast-iron sleeve, but consideration is being given to the use of stainless steel or carbon sleeves in production models, because of their better corrosion properties. Water precipitation and corrosion are unlikely, however, because of the temperature rise in the compressor. When running, the bearings generate their own hydrostatic pressure because of the relative motion of the bearings and the viscosity of the carbon dioxide. The viscosity of the carbon dioxide is very much lower than for conventional lubricating fluids and, broadly speaking, the design of the bearings is a revision of the variable parameters (clearance, peripheral velocity, surface finish) to obtain a useful load-bearing capacity.

With centrifugal blowers, the pressure rise is proportional

to the square of the speed. On a 50 c/s supply the highest speed obtainable with an induction motor is rather less than 3,000 r.p.m. and to get the required pressure rise at this speed would necessitate the use of a large multi-stage compressor. It is better to accept the expense and bulk of a frequency changer so that the compressor can run at about 12,000 r.p.m. At this speed a small single-stage impeller will give the required pressure rise, and the bearings and motor are both very much smaller.

The Dowty gas bearing compressor for B.C.D. consists of a centrifugal compressor and squirrel-cage induction motor built in a common pressure-tight casing. Shaft seals are not required and there is, consequently, little risk of gas leakage from the compressor. The journal bearings consist of very accurately produced journals running with small clearance in self-aligning sleeves. The thrust bearing is formed by a flat disc attached to the shaft running against a stationary carbon disc which is also self-aligning. Both discs are lapped optically flat and spiral grooves are cut in the face of the rotating disc. The viscous drag of the stationary plate on the gas in the grooves causes a pressure build-up between the discs, which tends to keep them apart when the shaft rotates.

Elsewhere in the B.C.D. equipment only non-metallic or ferrous materials are used, but the construction of the motor necessarily causes a departure from this general policy. It was originally intended that the motor should be in a dead pocket of gas, but heat dissipation has proved more troublesome than anticipated, and it has been necessary to bleed a small supply of gas from the back of the impeller into the motor unit. It is returned to the main B.C.D. gas circuit, upstream of the filter which immediately precedes the compressor. The stator windings are covered with a thick layer of bitumastic material and the motor will be varnished using an epoxy resin.

Future Developments

The sensitivity of B.C.D. is limited by various sources of extraneous counts including uranium contamination of the outside of the fuel element, A^{41} in the coolant gas, and gamma ray background. Inherent in the design of present detection equipment we have also residual activity on the wire and errors due to incomplete flushing of the precipitation chamber. Only the metallurgist can reduce the uranium contamination and so the art of B.C.D. design is essentially to be able to recognize as soon as possible a significant increase in counts resulting from fission products in the coolant gases. To this end, it is desirable to increase the latter as far as possible, both absolutely for statistical accuracy and also relative to other factors which should at the same time be reduced to the economic minimum. Uniformity of performance is also important, so that variations in the normal background count do not mask increases due to faults developing in fuel elements.

There is little doubt that even present equipment has excess sensitivity, and this, with the prospect of cleaner elements, and the probability that overall precipitator performance can be raised, makes it likely that the number of channels in a group will be increased. If the grouping is external to the reactor, savings are made in the B.C.D. equipment but co-ordinate systems of sampling are also being re-examined. With 16 samples grouped together a common pipe from each horizontal row of 16 channels is brought through the reactor pressure vessel to the selector valve. The channels are also grouped in vertical rows and common pipes brought out by further selector valves. The 256 channels comprising a block can be monitored by means of 32 pipes, or $\frac{1}{4}$ the number required when all pipes are brought through the pressure vessel. This fact alone represents a considerable saving, and the reduction in the cost of piping external to the reactor will also be very impressive. Some 40 miles of pipe were used for each reactor at Calder Hall.

The sensitivity of B.C.D. will be $\frac{1}{4}$ of that obtaining using the present system of grouping in fours, and equipment requirements will be halved. From the records available a suspect channel can be identified without further experiment. There are objectionable features however; it will be difficult to balance the various sample flows and very difficult to recognize and clear obstructions in any one connection. These are valid and important arguments, and much will depend on whether a satisfactory manifold can be designed.

Independently of these developments, considerable effort is being devoted to improving the performance and reducing the cost and bulk of B.C.D. equipment. This has been particularly successful in the case of the precipitator units. The improved beta/gamma discrimination of scintillation counters has allowed a marked reduction in the size of the shielding block which permits a much more compact design of precipitator unit, suitable for panel mounting. Advantage can be taken of this to mount the valve above the precipitator and so reduce the demands on floor space, and the work required on site. The virtues of pneumatic drives for both valves and precipitators are now generally recognized. As such a system would eliminate shaft seals, the possibility of leaks is greatly reduced. The development of a pneumatic drive could lead also to a drive system of reduced capital cost.

More fundamental advances in B.C.D. must await further experimental work. In the past, the necessary experimental facilities have been limited, and the U.K.A.E.A. was the sole repository of information. With the commissioning of Calder Hall, new ideas can be tested under conditions which, pressure excepted, approximate to those in which they would be required to operate. It is also possible now to purchase U^{235}, and test loops can be built and operated by private firms. The fission gas generator now in use at Brockhampton is believed to be unique and has already given valuable results. The fission products are obtained as a result of the bombardment of highly enriched uranium oxide by thermalized neutrons from an antimony-beryllium source. The number of neutrons available is only of the order of 10^7, so a very large area of exposed uranium is required.

Acknowledgments

While some of the opinions expressed are personal, many people have been responsible for the actual designs discussed. Apart from his colleagues the author is particularly indebted to Mr. L. G. Ralfe of A.E.R.E. and to Mr. D. S. Pettinger of A.E.I.-John Thompson Nuclear Energy Co., Ltd., for very helpful discussions on the principles and practice of B.C.D. Acknowledgments are also due to the C.E.G.B. and to the directors of A.E.I.-John Thompson Nuclear Energy Co., Ltd., and of Dowty Nucleonics, Ltd., for permission to publish.

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Power Reactor Simulator

Simplicity and Easy Maintenance of New English Electric Operator Training Unit

SIMPLICITY of construction, easy maintenance, and compact design are features of a new reactor simulator unit produced by The English Electric Co., Ltd., to enable operators under training to acquire experience and the "feel" of handling a reactor.

Operating Principles

As is generally known, a reactor simulator generally takes the form of an analogue computer which, when fed with input signals representing design functions and operating conditions, is capable of solving the fundamental equations governing reactor operation, and presenting output signals giving the same response as would be obtained with an actual reactor.

The accompanying block schematic diagram gives a general idea of the operating principles. There are three main computers for solving reactor power, heat transfer, and excess reactivity equations. These three are arranged in a closed loop and provision is made for injection at appropriate points of signals representing the following quantities and functions, all of which can be set at the control panel:—

1. Control-rod movement (fine control, coarse-stepped control, or adjustable constant-velocity movement).
2. Neutron source.
3. Fuel selection.
4. δK step.
5. δK scaling.
6. Built-in reactivity.
7. Mass flow of coolant.
8. Gas inlet temperature.
9. Power level and period trip settings.

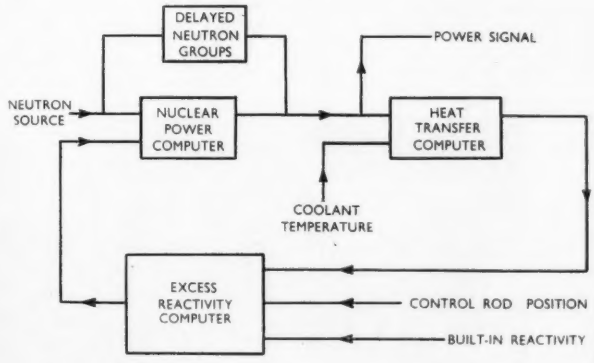
Signals, representing the built-in reactivity, fuel temperature, and control-rod position, are fed into the excess reactivity computer which produces the δK signal. This, together with a neutron source signal, provides the input to the nuclear power computer which simulates the appropriate transfer function together with the delayed neutron effects obtained from networks appropriate to the fuels selected by the fuel selection potentiometers on the control panel. The loop is closed by feeding the output of the nuclear power computer into the heat transfer computer together with a signal representing the coolant input temperature. An additional adjustment is provided for mass flow.

The output of the simulator operates the appropriate instruments on the control panel, showing:—

1. Excess reactivity.
2. Control-rod position.
3. Reactor period.
4. Nuclear power.
5. Fuel surface temperature.

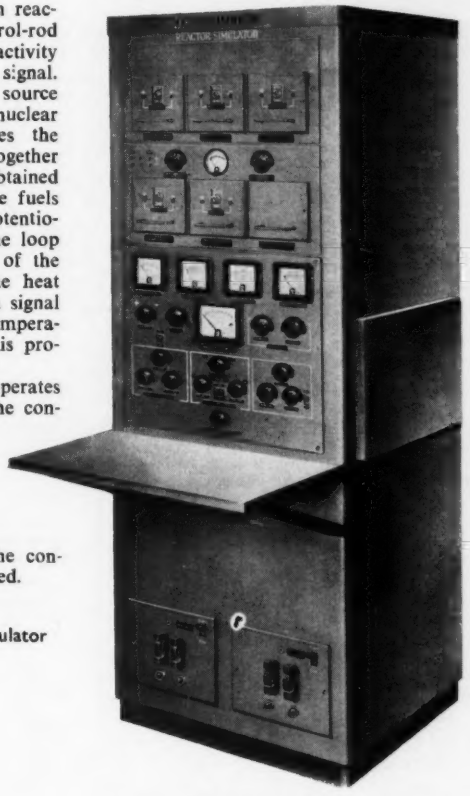
Arrangements are made for the connection of a recorder, if required.

Block schematic diagram of simulator circuits.



Construction

An upright cubicle was considered more compact and convenient than a console unit, and the dimensions are 6 ft high, 2 ft wide, 2 ft deep. The cubicle is divided into three sections, the top section housing the computer amplifier units; the middle, the control gear and instruments, and the lower section housing the power pack units for amplifier supplies from a standard single-phase 50-cycle supply.



General appearance of unit showing hinged flap for accommodating recorder.

Immediately below the control panel is a table-top for the operators' use. A second table-top at the same level, which can be folded out of the way when not in use, is provided for accommodating a recorder, when this is required.

The amplifiers are not provided with built-in automatic drift correction, but manual adjustment for drift can be carried out by set-zero switches and screwdriver-operated potentiometers on the front panel of each amplifier unit.

Each of the amplifier units is mounted on a withdrawable chassis with mating plugs and sockets, and a lead is provided for any unit to be maintained or tested outside the cubicle. A spare amplifier unit is provided, being connected in circuit, as and when required, via input and output jacks on the front panel.

Expansion at Erith

New Facilities at Research Laboratories of G.E.C. Atomic Energy Division

RESEARCH facilities of the Atomic Energy Division of the General Electric Co., Ltd., have undergone considerable expansion since they were first described (*Nuclear Engineering*, September, 1956, p. 228). At that time the C.E.A. power station tenders were in process of being submitted, and the main task of the laboratories was, roughly speaking, to provide *ad hoc* answers to a number of problems concerned with the design of the first stations. The expansion is largely concerned with detailed investigation towards the improvement of original designs to increase efficiency, reduce costs, and adapting them to meet special requirements, particularly for overseas. The establishment now has a staff of 450 against 200 eighteen months ago.

Heat Transfer Work

The heat laboratory, one of the original buildings, still has a number of its original test rigs in constant use, but the cessation of some studies, and the transference of work to other laboratories has enabled additional apparatus to be installed.

The original apparatus for assessing heat transfer characteristics of heat exchanger tubing, by passing steam through tubes in a wind tunnel and measuring the amount condensed, is still in operation, but has been augmented by a new rig, capable of a greater mass flow of air, thus extending the scope of investigations. (This method of performance measurement was described by A. Lymer, one of the Simon-Carves contingent at the laboratories, in *Nuclear Engineering* for December, 1957, p. 504.)

Heat Transfer on Fuel Cans

The original work on fuel can heat transfer, in which the heat is supplied by a close-fitting stainless-steel tubular element, is still proceeding. In the main apparatus, the complete unit is placed within a lagged tube the same diameter as the reactor channel, and tested in an atmosphere of carbon dioxide at correct pressure and temperature, pressure points allowing accurate measurement of friction factors. This has been supplemented by two rigs that utilize air as a cooling medium, one being arranged for forced draught, and the other for induced draught. While these do not exactly simulate working conditions, they are valuable for a rapid assessment of the performance to be expected. They, also, presumably, enable a more certain comparison between atmospheric air and pressurized carbon dioxide than can be obtained by calculations and assumptions.

Turbulent Flow Patterns

A considerable amount of information can be obtained on turbulent conditions around finned tubes by the use of water models, in which water flow is utilized in place of gas, and patterns formed by marker dyes or small polystyrene spheres are observed. Two such rigs are available, one for fuel elements, utilizing a longitudinal flow in a "Perspex" tube. The other, for heat exchanger banks, uses "Perspex" models of portions of the tubes, arranged in the required pattern, in a horizontal channel which is illuminated from the side and can be photographed from above. The length of the streaks shown by the polystyrene spheres is a measure of their relative instantaneous velocities at different points, and enables dead spot eddies and local reversals of flow to be instantly observed.

Graphite Permeability

Work is proceeding on the measurement of the permeability constant of reactor graphite sleeves. Carbon dioxide at the operating pressure is supplied to the centre of the sleeve, which is contained in a pressure vessel and allowed to escape from the outside of the sleeve, through a valve to atmosphere, measurements being taken of the flow rate, pressure differential across the sleeve, etc.

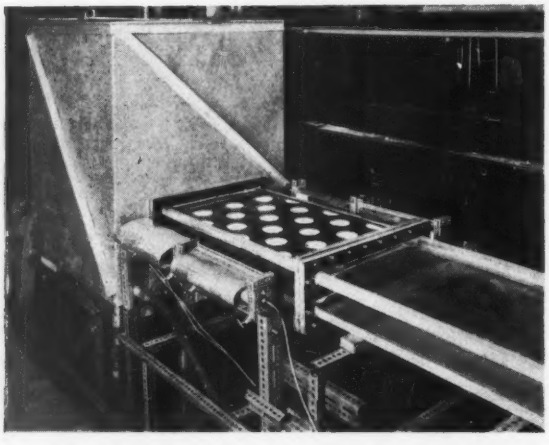
The "Hot-Box"

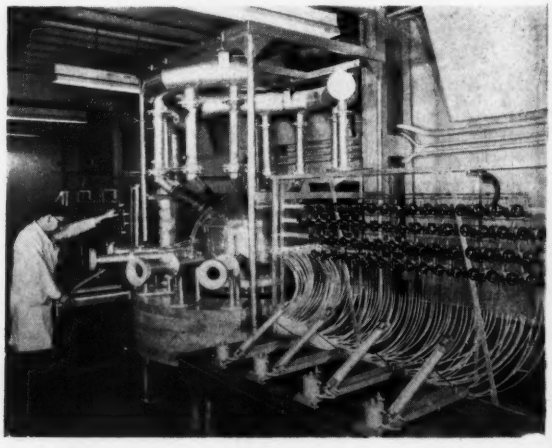
A full-size model of a reactor standpipe is connected at its lower end to a pressure vessel which can be heated and filled with CO_2, thus giving actual reactor working conditions enabling control mechanisms or gas sampling valves, etc., to be life-tested.

Mechanical Engineering Laboratory

A scale model of the Hunterston pressure vessel is being used to investigate gas flow phenomena. The "Perspex" sphere which contains it is 42 in. diameter, and was described in *Nuclear Engineering* for July, 1957, p. 303. The core, made of duralumin, resting on a scale model of the support grid, has tubes representing the fuel and control rod channels, to give scale-effect resistance to gas flow. Air is drawn through the outlet

(Below) Water channel for investigating flow pattern through a bank of steam raising tubes. Flow patterns are shown by polystyrene particles carried in the water stream.

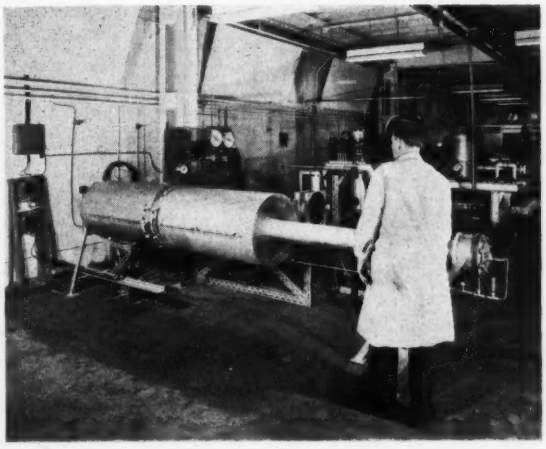




(Above) One-twentieth scale model of Hunterston reactor, for investigating gas flow. Note the large number of pressure point tubes.

ports of the sphere and pressure measurements can be made at a large number of points throughout the reactor. It is thus possible to investigate the symmetry of the gas flow through the reactor, the effect of shutting down one or more of the gas circuits, or the influence of gagging various channels.

Thermal shock caused by the insertion of a cold fuel element into a hot reactor is being investigated with a rig consisting of a horizontal channel, 14 ft long and 6 in. bore, filled with carbon dioxide at working pressure. A length of this channel is heated at one end by two 5 kW elements arranged end-to-end so that, by varying separately the supplies to the two heaters, the temperature gradient can be varied. The fuel element under test is mounted on a carriage which can be moved along the channel, into the heated zone, by means of a chain driven by a hand-wheel, and the effects of different rates of insertion can be studied.



(Left) Rig for testing fuel elements under thermal shock conditions.

The effects of temperature transients on reactor support skirts can be studied by a ¼-scale model of a section of pressure vessel and skirt mounted in a sheet steel enclosure encased in firebrick, with carbon dioxide circulated over its surface to simulate the gas flow in the reactor. The gas is heated by means of a 20-kW electric heater, and the velocities and temperatures employed in the model are arranged to produce effects equivalent to those that will be experienced in the full-scale structure. The temperatures at various points on the model are measured by thermocouples and are recorded on a 16-way recorder.

Uranium-can Heat Transfer

Two test rigs are being used in the mechanical engineering laboratory for measuring heat transfer characteristics between uranium and can. One, used for basic research, has discs of uranium and of the canning material arranged face-to-face. One face is then heated and thermocouples are used to determine the temperature distribution along the heat path through the discs. By this method, the effect of using different canning materials, different surface finishes, and different gases to fill the small residual spaces in the can, may be determined.

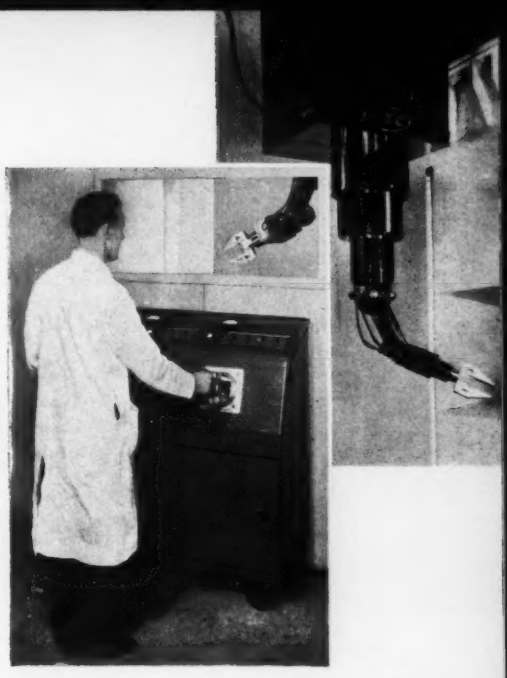
The second rig is used for tests on complete fuel elements. So that the uranium can be raised to the temperature it will attain in the reactor, it is made in tubular form and an electric heater is inserted in the bore. The complete element is enclosed in a pressure vessel containing Dowtherm, which boils at about 453°C with a vapour pressure of 150 p.s.i.g. These are the temperature and pressure conditions that will exist within the reactor, and the use of Dowtherm therefore eliminates the need for a comparatively complex system for supplying pressurized gas to the apparatus. Continuous refluxing of the Dowtherm is obtained by providing a small condenser in the top of the pressure vessel. Thermocouples are provided to measure the temperatures at various points.

Other work being carried out in the mechanical engineering laboratory include bearing friction in pressurized carbon dioxide, shaft sealing, sensitive methods of leak detection for heat exchanger tubes, and various welding problems.

Power Manipulator

An interesting development is a power manipulator for active cell work, having a grip of up to 150 lb and a lifting effort of up to 750 lb. The general arrangement can be seen from the accompanying illustrations. In addition to the normal travel and traverse movements of the gantry spanning the works area, the body of the manipulator is telescopic. The arm joints are capable of 180° movement; the shoulder joint and wrist are both arranged for continuous rotation.

All movements are powered by 3-ph. squirrel-cage motors with variable frequency control of speed; there being a number of motor alternators housed in a control cubicle. The use of squirrel-cage motors avoids the necessity for wound rotors or brushgear, and makes for a much more rugged construction, particularly with the smaller motors.



(Above, right) Power manipulator and control desk.

Particular care has been exercised in the choice of materials, in view of the intense gamma radiation they will have to withstand; silicone and glass insulation for coils, mica for slot linings and phenolic-bonded asbestos for brake linings. Every movement is provided with brakes, to ensure that loads are held in the case of a power failure.

Two joystick-type handles provide the control, the motions being arranged to follow logically the movements of the manipulator and the speed of each movement being proportional to the joystick displacement. Switches are provided for locking any of the motions in a given position. The control console also contains a grip indicator, operated by a transducer in the mechanism. The scaling of the indicator is non-linear, to bring the 15-lb marking at midscale. An audible signal can also be given so that the operator can concentrate on watching the manipulator, without danger of crushing delicate objects.

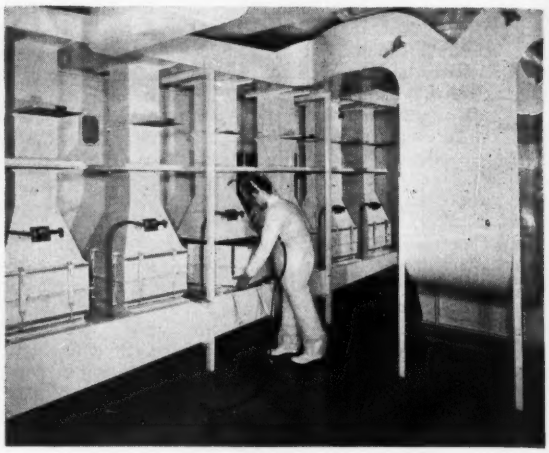
Beryllium Laboratory

The advantages of beryllium as a high-temperature canning material hardly need stressing but it has, of course, a number of disadvantages, not least of which are brittleness, difficulty of welding, and extreme toxicity. An extensive investigation into beryllium is taking place in a new laboratory designed and built specially for the purpose.

Methods of eliminating the hazards arising from the metal's toxicity have been thoroughly investigated by interested authorities both in this country and in the U.S.A., and, as a result, a number of recommendations have been made. The principal feature in the standards adopted by the United Kingdom Atomic Energy Authority, and applied in the design of the new laboratory, is the necessity of obtaining a working atmosphere where the average atmospheric concentration of beryllium does not exceed 2×10^{-6} g/m^3 throughout the working day. In addition to the

(Above) Beryllium laboratory; working boxes for oxidation experiments.

(Below) Beryllium laboratory; operator in pressure suit changing a filter.



general precautions necessary in the design of the complete installation in order to achieve this standard, considerable care must be devoted to each operation involving beryllium and special techniques may be required in particular cases. For example, dusty operations such as grinding require more precautions and protective installation than some other, non-abrasive, operations.

The laboratory is a two-storey brick building with a concrete roof. For all normal purposes, the only means of entry is through a change room which is divided into two parts separated by a barrier.

The laboratory itself is divided into two areas, A and B. The A area is designed for operations of greater potential hazard, and has a higher air-extraction rate than B. Double emergency doors open out of the building from laboratory area B and these, though normally sealed, are also used where necessary for the introduction of plant and machinery.

The first floor houses the service room and the extract-filter room, and also provides some office and laboratory accommodation for the Medical Radiobiology Department.

The walls and ceiling are finished in a high-gloss paint, to facilitate cleaning, and every effort has been made to keep the laboratory free from dust traps. All the electric wiring is buried beneath the plaster, and all switches and sockets are flush fitting. The light shades are sealed to the ceiling.

The whole of the floor is covered with heavy-gauge linoleum, coved to the walls, and contains twenty-five drain points. Liquid effluent is discharged to a 400-gallon inspection and holding tank, which can be monitored. This tank acts as a water seal on the laboratory drains, so that air cannot be drawn into the building via the drainage system. A small filter is installed at each of the points where there is a danger of finely divided beryllium being discharged into the drain.

Since much experimental work is to be carried out in a pressurized carbon-dioxide atmosphere, a supply of this gas is piped round the laboratory at a pressure of 150 p.s.i.g. A normal supply of compressed air is available but, in addition, a separate compressor is installed to provide a low-pressure, clean air supply for air masks and pressurized suits.

Ventilation System

The laboratory areas are completely air-conditioned by means of one central inlet air duct, and two ranges of extract ducting. A fan with a capacity of 6.000 cu. ft/min draws air into the building through a bank of filters followed by a steam-to-air heat exchanger thermostatically controlled to maintain an inlet-air temperature of 75°F. Filtration is necessary at this point in the system in order to increase the effective life of the high-efficiency extract filters.

The extract system is more complex. It consists basically of a fan drawing air at the rate of 8.000 cu. ft/min from the laboratory, through 12 Vokes Absolute filters. These are arranged in two banks of six, coupled in parallel to the extract fan. Each filter is individually mounted in a cell on the manifold, in order to minimize the hazard during filter changing. The Absolute filter has a guaranteed efficiency of 99.95% removal of particles in the range 0.1 to 0 5 micron in diameter. For particle sizes greater than 1.0 micron, the efficiency of removal is virtually 100%. The state of each filter is shown by a manometer.

Working-boxes

Initially, all experimental procedures involving the handling of beryllium will be carried out in ventilated working-boxes, each designed around a specific operation. All operations involving the formation of beryllium dust or chip (for example, machining, abrasion and welding) are confined to Laboratory A, where the highest ventilation rate is available.

Operating Procedure

In spite of the elaborate precautions taken in the design of the installation, it is essential, if all risks of beryllium poisoning are to be completely avoided, for each laboratory operation to be proved safe before it is allowed to be conducted on a routine basis, and a new operation is initially performed in protective clothing with an external air line, while air samples are taken at a number of points in the immediate vicinity of the operator, to ascertain that the operation can be conducted without exceeding—or approaching even—the maximum permissible level for atmospheric beryllium concentration. Once this has been established, the work can be continued without an air line or the associated protective clothing.

Beryllium monitoring is difficult, and, at present, the use of spectrochemical techniques on a batch-sampling basis provides the best safeguard. In collaboration with the G.E.C. Research Laboratories at Wembley, a sampling and analytical scheme has been established using air samples of about 10 cubic metres. By the methods employed, as little as 1.5×10^{-8}g of beryllium can be detected.

In addition to air monitoring on specific operations, routine background samples are taken daily in the laboratory over a period of eight hours. Additional monitoring is employed for any unusual circumstances such as swabbing down machines, or for any minor spills; on these occasions, fully protective clothing is worn.

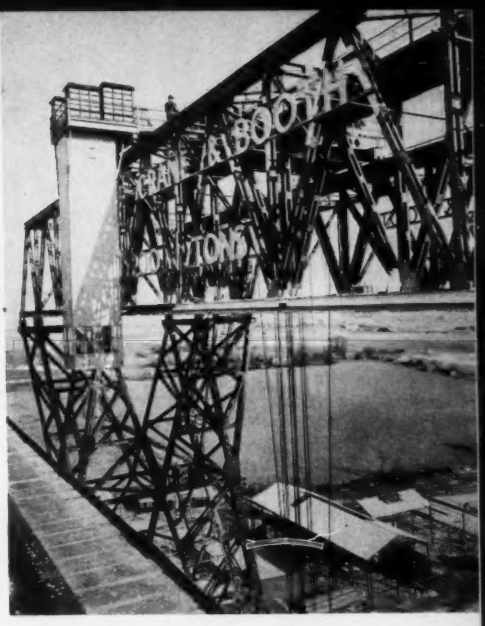
Beryllium Storage

A fireproof safe is used as a store in which all beryllium is kept when not in use and when the laboratory is closed.

The disposal of solid waste contaminated with beryllium will be carried out in the manner adopted by the U.K.A.E.A., that is by burial in sealed containers.

Bradwell's Goliath Crane

Expected to Save 3-6 Months' Station Construction Time



The bridge from the erection platform.

DOMINANT feature of the Bradwell site, and visible for miles around, is the Goliath crane built by Clyde Crane and Booth, Ltd., of Rodley, Leeds, an associate company of Clarke Chapman and Co., Ltd., the member company of the N.P.P.C. responsible for handling heavy loads on site. With a span of 178 ft and a height of 177 ft (140 ft clear lift) rated at 200 tons, the crane is believed to be at present unique in the size of load associated with such a span, although it is known that even larger cranes are under construction.

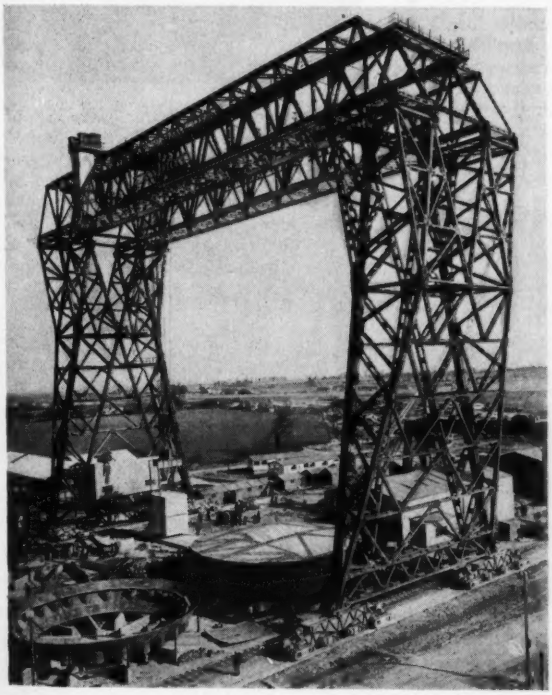
By courtesy of the Nuclear Power Plant Co., Ltd., we were recently able to carry out an inspection, and to see the crane undergoing tests. The massive construction of the crane can be seen from the accompanying illustrations. Each side is supported on eight four-wheel bogies, running on standard rail track, four bogies on each side being driven by 20 h.p. motors for the long travel motion. "Selsyn" gear is fitted so that any cross-winding that might possibly occur is indicated in the driver's cabin, and can be corrected by individually driving one side. The rate of travel, fully loaded, is 50 ft/min.

The main hoist is powered by two 50 h.p. motors, and lifts a 200-ton load at 4 ft 9 in. per minute. There is an auxiliary hoist, capable of lifting 30 tons at 33 ft/min. Traversing of the crab is by two 20 h.p. motors at 50 ft/min. All motors are of Clarke Chapman manufacture.

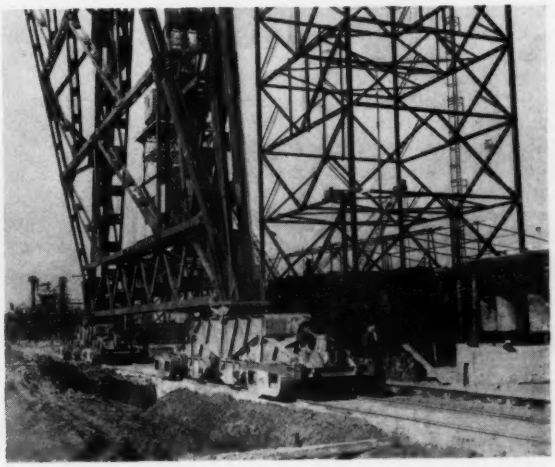
The crane is entirely self-contained and the generator house is carried on the easterly side of the structure. Power is provided by a three-cylinder Crossley Diesel engine of the two-cycle scavenge-pump type coupled to a 200-kW Clarke Chapman generator. A separate Diesel-driven compressor is provided for starting purposes.

The crane weighs 800 tons and has taken 14 months to build. It has been constructed with high-tensile bolts in place of rivets, so that it can be dismantled and used again on other sites. The steelwork was supplied by the Tees Side Bridge and Engineering Works, Ltd.

Questions have been raised as to the economy of such a crane, which cost in the neighbourhood of £400,000, but it is predicted that its use will save a minimum of three months and possibly as much as six months on the completion of the contract. With its capability of straddling the entire station (except the turbine house) and a length of track of 1,200 ft, it can pick up the heaviest pieces of equipment and transport them with ease to their appointed location. It will, for example, allow the pressure vessel sections to be fabricated in the assembly area and then transported to their final position, and will receive and deposit the heat exchanger units. While much of this work can be done with derricks and sheer-legs, the time and labour involved in changing their location is not their only drawback. Even more inconvenient is the necessity for leaving fair leads for the associated guy ropes and winching tackle, in fact the necessity for leaving guy-rope clearance may often delay the construction of other work. The new crane will allow construction on surrounding work to proceed unhampered.



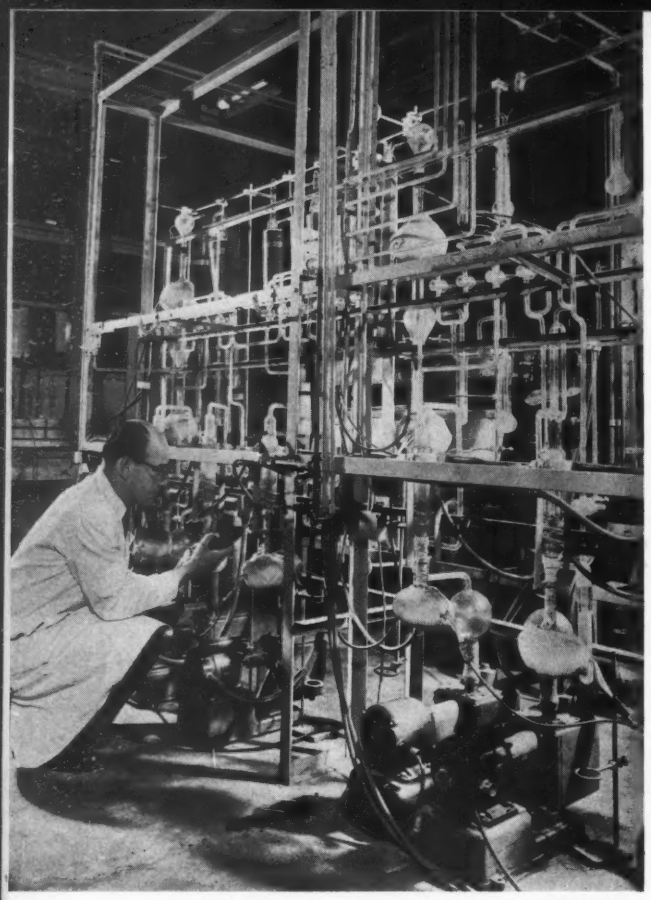
General view lifting 200 tons.



One of the bogie units.

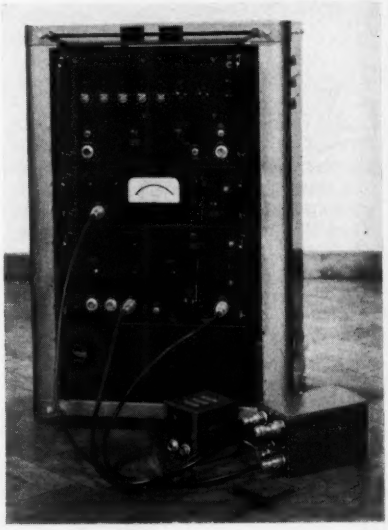
INSTRUMENT SURVEY

Classified details of new instruments developed for nuclear engineering applications. Particular attention is paid to exhibits at the recent Physical Society Exhibition and the International Instruments, Electronics and Automation Exhibition which takes place at Olympia, London, from April 13 to 25. Exhibitors at the I.E.A. are denoted by means of an asterisk. Readers requiring further information on any item should enter the number given at the end of each paragraph on the Reader Service card enclosed with this issue.



(Left) Purifying system associated with the manufacture of BF_3 proportional counters. The process involves heating a calcium borofluoride complex and subsequently purifying the enriched BF_3 gas (20th Century Electronics).

(Right) 127A counting equipment by Ericsson Telephones.



Nuclear Instruments for Reactors

A new amplifier by Ericsson Telephones is designed for operation in a reactor shut-down channel, providing trip facilities at a power level which can be accurately pre-set. Input is derived from a conventional ion chamber. Several unique design features include a transistorized chopper which compares d.c. input with a reference voltage.

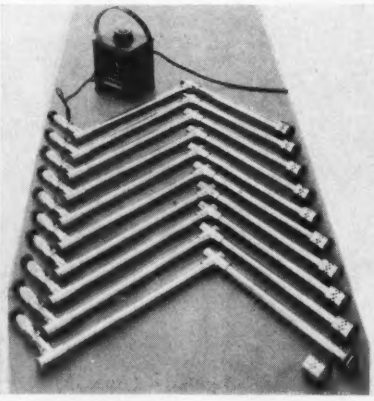
1000 ★

The 127A counter by Ericsson Telephones is a general purpose equipment particularly suitable for reactor pulse counting channels. The complete equipment consists of a pre-amplifier, amplifier discriminator, scaling unit, E.H.T. unit, logarithmic ratemeter, linear ratemeter, quench unit and a timing unit.

The pre-amplifier has a gain of 5 or 50 and the maximum sensitivity referred to the input terminal is 200 μ V with the full gain of the amplifier discriminator. The latter has a maximum gain of 20, variable integrating and differentiating time constants and seven paralysis times. The sensitivity is fixed at 0.2V. The scaling unit has a resolution time of 2 μ sec and a maximum mean counting rate of 2×10^5 pulses per second. The maximum count of 10^7 is displayed on dekatrons and the input pulse sensitivity is 10V, positive or negative polarity.

The E.H.T. unit provides a stabilized output voltage continuously variable from 300 to 2,000V at a maximum current of 300 μ A. The logarithmic ratemeter indicates count rates from 2 to 2×10^5 pulses/sec accurate to 10% and the linear ratemeter covers 0 to 2×10^5 pulses/sec in five ranges accurate to $\pm$ 1% of full scale deflection. The quench unit is intended for G.M. applications where the amplifier units are not required. Six paralysis times are provided. Finally, the timing unit offers a pre-set time or pre-set count facility, using a 1 kc/s tuning fork as a time base.

1001 ★



Ten double-right-angle Introscopes. These units are installed at Calder Hall for viewing fuel elements on removal from the reactor (Foster Instrument Co.).

Introscopes for remote viewing of small diameter ($\frac{1}{8}$ in.) holes to a limited depth and jointed units with total operative lengths of over 80 ft are made by the Foster Instrument Co. These instruments have built-in illumination and several different angles of view can be obtained by using interchangeable viewing heads.

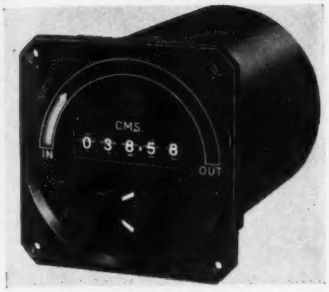
1002 ★

A new series of nuclear instruments is being introduced by Philips Electrical, including a pre-amplifier, linear amplifier, electronic timer, single-channel analyser, H.T. power unit and 5 kV supply.

1003 ★

A new control-rod fine position indicator by Sperry Gyroscope comprises a servo-driven indicator having a presentation combining within one bezel information as to the general position of the rod, its absolute position within 0.1 mm, together with an indication of the direction of the control-rod movement and its speed.

1004 ★



Sperry control rod position indicator.

Physical Instruments

For thermocouple temperature recording, a new d.c. amplifier and microvoltmeter by W. G. Pye can be easily rack mounted: single and three channel models can be made for special requirements. The amplifier and microvoltmeter is of exceptional zero stability and sensitivity, providing, on the recorder, full-scale deflections for 0.2°, 0.8°, 4.0°C or 8μV, 32μV, 160μV.

1006 ★

On subject of flow measurement and control, a very wide range of units is now manufactured by George Kent. The Commander series features modular construction and rationalized design. On the control side, the company's latest achievement is the Mk. 30 range of pneumatic control units.

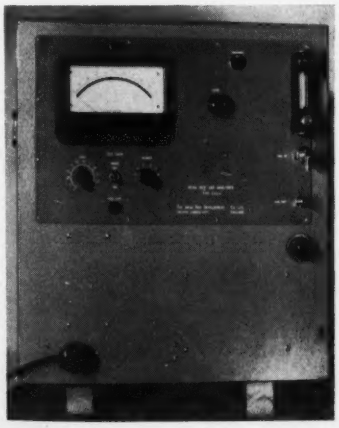
1007 ★

Miniature recorders, indicators and control stations have been developed by Electroflo Meters. These units are particularly suitable for inclusion in graphic control panels.

1008 ★

The range of differential converter transmitters by Honeywell Brown has now been widened so that the lowest pressure differentials can be measured with great accuracy.

1009 ★



N.i0 leak detector by Infra Red Development Co.

Of the many different gauges made by Firth Cleveland Instruments two are of especial interest. The Hydrostatic gauge, which is operated by compressed air, can be used for remote reading of bank contents. The Pacitor Electronic gauge is designed for installations where float-arm, air or diaphragm-operated gauges are unsuitable.

1010 ★

A dissolved oxygen analyser by Cambridge Instrument Co. employs a novel electrochemical method of detection. This continuously analysing and recording outfit has been expressly designed for checking high pressure, high temperature steam systems. The instrument features an improved method of calibration with means of detecting and assessing errors due to leaks in the equipment itself. It is capable of recording oxygen concentrations to the order of 0.001 part per million.

1011 ★

The GDI leak detector by Edwards High Vacuum will detect leaks in the region of 1/50 oz of hydrogen per year. Samples of air from suspected areas are continuously induced over an electrically heated element, the temperature (and resistance) of which changes when leakage gas is induced.

1012 ★

A useful instrument for the detection of leaks in pressure vessels is the SC/LA analyser made by The Infra Red Development Co. It has an internal pump, throttle and flowmeter. Another analyser, the SC/M, can be employed as a humidity probe in pressurized water systems.

1013 ★

The Muirhead range of synchros and servomotors now covers more than 150 types in frame sizes 08, 10, 11, 15, 18 and 23.

1014 ★

Amongst the extensive range of Ketan synchros and servo components is the new size 15, a 400-cycle precision-integrating tachometer.

1015 ★

Nagard's new d.c. coupled vectorial time-base, Model 3401, provides facilities for checking servo systems. It will produce circular or spiral c.v.t. displays over a calibrated range of 10 sec. to 0.02 sec/r.p.m. in nine steps.

1016 ★

The latest multi-channel strip chart recorders by Elliott Bros. incorporate miniature moving coil movements arranged to record simultaneously on a single strip chart in banks of 2, 3, 4, 5 or 6 units, each movement recording on a 3 in. wide zone. A wide choice of chart speeds is available. The instruments are robust and applications cover a wide range of simultaneous recordings: for example, three-phase currents and voltages, speeds, revolutions and frequency (the last with the Elliott full-wave bridge network unit), can be simultaneously recorded with a minimum amount of equipment. One version developed in collaboration with the Nuclear Power Plant Co. is for turbine supervisory recording and charts megawatts, revolutions per minute, and high and low pressure cylinder expansion.

1017 ★

Up to eight variables can be recorded simultaneously on the latest Kelvin Hughes dynamic strain recorder. Deflections of up to ±2 cms are obtainable with a 5-channel unit and up to ±1.2 cms with an 8-channel set.

1018 ★

(Right) Displacement level transmitter (Evershed and Vignoles).

(Left) Ketay Size 15 precision integrating tachometer.

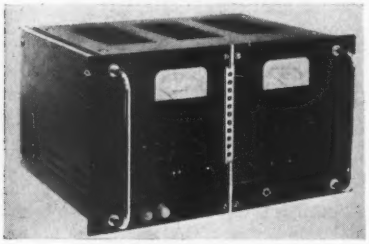
Liquid sodium level transmitters for the Dounreay fast breeder were supplied by Evershed and Vignoles. A modification of their standard E R 87 unit, the displacer chamber is replaced by a long, stainless-steel tube connected to the transmitter head by a block of mild steel which forms the biological shield. The transmitter head cover is clad in thick M.S. to give additional shielding. The space above the surface of liquid sodium in the transmitter tube is blanketed by nitrogen at approximately 90 p.s.i.

1019 ★

Laboratory Instruments

The Isotope Developments scaler, type 1700, has automatic pre-set count and timing facilities. It includes a four-range ratemeter, pulse amplifier, stabilized high-voltage supply of up to 2 kV, simple pulse analyser and power supplies for an external quench unit or pre-amplifier. In conjunction with a G.M. tube or scintillation counter it forms a self-contained counter.
1020 ★

General Radiological are adding several new units to their extensive range of nucleonic instruments. A transistorized scaler, NE. 075, for general purpose use, can be included in a reactor flux scanning equipment. The scaling factor is 10^5 and the resolving time 250 μ sec.
1021 ★

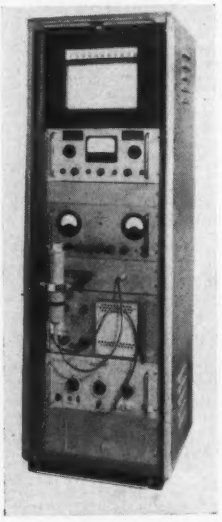


Ratemeter, type M430 by General Radiological.

A new Ekco ratemeter of improved accuracy and stability employs a single-channel pulse height analyser, which incorporates both constant voltage and constant percentage channel widths, as well as a wide band amplifier. This instrument, N600, can be used as a simple gamma spectrometer analyser in conjunction with a standard scintillation counter and suitable recorder. Of unit construction, the N600 has an overall resolving time of about 3 μ sec.
1022 ★

To supply highly stabilized E.H.T. for various types of radiation detectors Philips Electrical have developed an electronic circuit panel, PW 1051. The E.H.T. can be varied from 700 to 2,000 V by coarse and fine controls with a stability of ± 0.1% over an 8-hr period, with voltage regulation of ± 0.1% at 2,000 V for a mains fluctuation of ± 10%. The panel contains the scaling circuits; provision is made for both fixed count and fixed time operation with a resolution time of 1 μ sec. The accuracy on fixed count is within three counts on any scale. Ratemeter facilities are offered with a Philips 10-in. recorder showing the final trace on a roll chart, providing 27 ranges from 30-12,800 counts/sec, for full scale deflection.
1023 ★

For use in gamma spectrometry, the Dynatron single-channel scanning pulse analyser, type N 102, comprises a fast threshold amplifier followed by two discriminators, and gives an output pulse when the lower discriminator only is triggered. The threshold (lower discriminator) level is set by means of a potentiometer which may be operated manually or driven by a synchronous motor. This means that the threshold can be scanned whilst the channel width remains fixed at a value which can be set between 0-50 V. The output of the analyser may be fed to either a scaler or a ratemeter. If the latter is used a continuous spectrum record can be obtained by feeding the ratemeter output to a suitable chart recorder.
1024 ★



Dynatron gamma spectrometry set, type N 102.

A timing unit, type 1179A, which accurately operates a set of change-over contacts at pre-selected intervals of ½ to 30 minutes in ½ minute steps with an accuracy within 0.03 sec over the whole range, has been developed by Associated Automation in conjunction with A.E.R.E., Harwell.
1025 ★

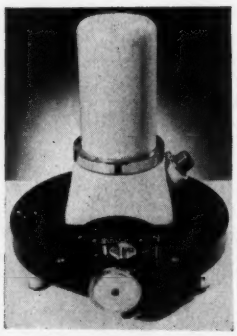
Scintillation Counters

The 20th Century range of photomultipliers for scintillation counting has been increased and new dynode structures have been developed in addition to the existing venetian blind types. To convert fast transient light signals into high current information that can be recorded without the use of an intermediate amplifier a focused type of tube has been devised in conjunction with A.W.R.E., Aldermaston. The tube has five stages of multiplication and is capable of output currents well in excess of 100 mA. A new box-type dynode assembly has been incorporated in tubes of 28 mm and 14 mm o.d. These tubes have exceptionally good stage gain and good collection efficiency of photoelectrons.
1026 ★

A new Ekco ultra-light-weight scintillation counter, N618, is for use with ratemeters and scalers without an amplifier, a separate wide-band amplifier with a range of switched gains is available. Of small physical size, the N618 is watertight and can be cold sterilized, making it suitable for use in operating theatres. A set of collimators is supplied with the counter to define accurately the sensitive solid angle.
1027 ★

The new Ekco N612 beta scintillation counter has been developed for counting low energy beta particles; it is especially useful for the assay of carbon 14 and tritium. An interlocked shutter prevents light falling on the photomultiplier tube when sources are changed and the source/phosphor container is optically coupled to the photomultiplier cathode by a suitable liquid. Using carbon 14 at room temperatures, overall counting efficiencies of 50% or more are obtainable.
1028 ★

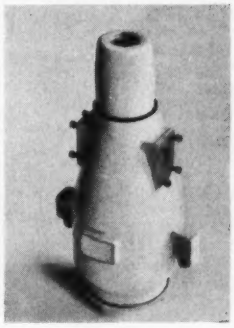
Nash and Thompson have introduced several new additions to their range of plastic scintillators. The company has prepared typical response curves of sodium iodide, anthracene crystals and various plastic scintillators to different types of radiation.
1029 ★



Large area scintillation counter (Mervyn Instruments).

An interesting large area alpha scintillation counter has been designed by Mervyn Instruments for checking samples of low activity. The instrument incorporates a 3-in. dia sample holder. The shutter is interlocked with the mechanism for opening the counter so that the phosphor cannot be accidentally unmasked.
1030

The 700 scintillation counter head by Isotope Developments is available either with a built-in amplifier to suit existing scalers and ratemeters or with a direct output. The head is shielded in all directions except for an opening to which interchangeable collimators can be fitted. These allow for accurate location of radioactive deposits in the human body or for general measurement of uptake and body background.
1031 ★



Isotope Developments 700 scintillation counter head.

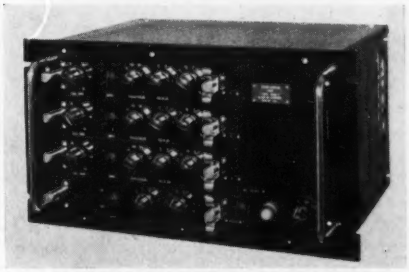
A very wide range of scintillators is available from Nuclear Enterprises (G.B.) Ltd. Products include plastic scintillation flow cells for beta and alpha emitters and for the counting of carbon 14 and tritium in aqueous solution; fine filaments (up to 2 mm) for nuclear track chambers; large area detectors for cosmic ray and fast particles, and samarium-loaded scintillators. The company is just completing a multi-channel scintillation spectrometer for industrial tracer investigation.
1032

Additional Equipment

Fully automatic counting facilities for Geiger or scintillation counters are provided in the new AC300/6 equipment introduced by Panax Equipment. The unit will both time a pre-set count or count against a pre-set time. The count and timing channels each have six plug-in dekatron units giving a range of pre-set counts up to 10^6 and pre-set time up to 10,000 sec for timing pulses of 100 p.p.s.
1033

AC 300/6 automatic counting equipment (Panax Equipment).

Many different sizes of neutron counters are now available. One of the leading companies in this field, 20th Century, has extended the range of BF_3 slow neutron counters, fast neutron counters, and fission ionization chambers.
1034 ★



Dynatron coincidence unit, 1036 c.

For high speed counting Mullard offer a new hot cathode decade counter and selector tube capable of handling input pulses up to about 1 Mc/s. The tube employs a combination of magnetic and electrostatic fields.
1035 ★

Fast neutron monitor, NE 046 (General Radiological).

Based on a design by Geisow of the Automatics Group, A.E.R.E., the automatic sample changer, D 4135 by Lab-gear is of great assistance in assay work. Special holder trays for planchet sources are used in conjunction with a drive feed comprising two parallel helical shafts.
1037 ★

Panax Equipment have recently redesigned their universal castle, type LC/2. Suitable adaptors, contact assemblies and extension rings enable the LC/2 to be used with the various shapes and dimensions of Geiger counters available.
1038

The E.M.I. corona power supply is designed for use with photomultipliers, Geiger-Müller counters and other applications requiring accurate e.h.t. voltage at low current. Maximum output current is 100 μA and stability ratio 100 : 1. E.M.I. have also developed an eleven-stage photomultiplier with 12-in. diameter windows.
1039 ★

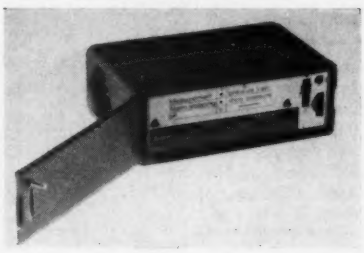
Monitors

A new unit by General Radiological is the NE 046, a portable self-contained monitor for the general purpose measurement of fast neutron intensities within the range 0.15 to 15 MeV.
1036 ★

A new portable transistorized contamination monitor by Burndept is capable of measuring alpha, beta, gamma and thermal neutron radiation. Battery-operated, it comprises two main units, a ratemeter and a probe. An eleven-stage photomultiplier forms the basic component of the probe. Selective detection of alpha, beta, gamma and thermal neutrons is obtained by the use of interchangeable phosphors. High overall sensitivity is ensured by the use of a scintillation counter as detector. Output pulses from the probe are fed into the transistorized ratemeter where they are amplified and integrated. Indication of count rate is provided on a moving-coil meter.
1040 ★

A new personal monitor by Grove Electronics warns the user audibly when radiation exceeds a pre-set level, either 5 mr or 25 mr. This battery-operated device makes use of transistor and printed circuit techniques: overall size is 7 in. by 2½ in. by 1 in.; weight, 15 oz. Battery life is approximately 45 hours irrespective of warning.
1041 ★

Designed specifically for X-ray and gamma-ray operators is a new radiation warning device by Radiatron. The device comprises a small ionization chamber arranged to give warning when the accumulated dose reaches 30 mr. Battery-operated, the unit weighs 12½ oz.
1042 ★



Personal radiation monitor by Radiatron.

For measuring radiation intensity in close proximity to high level sources of β and γ radiation Avo have developed a new hot spot monitor. The ionization chamber—held by the operator at the remote end of an extending rod—is constructed of suitable air-wall characteristic materials, and has a volume of 150 cm³. The indicator unit is easily carried by the operator and radiation is observed directly on a 5-in. logarithmic scale. Readings can be obtained from 0.1 r/hr to 500 r/hr.

1043 ★

Another Avo radiation monitor, Model No. 1, is light, portable and self-calibrating. Battery-operated, it will measure x, β and γ radiation on a 5-in. logarithmic scale calibrated from 1 mr/hr to 5 r/hr. The detector component of the instrument is an ionization chamber, normally covered by a metal screen which is removed when it is desired to obtain an estimation of β radiation. The ionization chamber has a volume of the order of 600 cm³. The window is approximately 12 in.² in area and is made from 0.00025-in. aluminized Melinex.

1044 ★

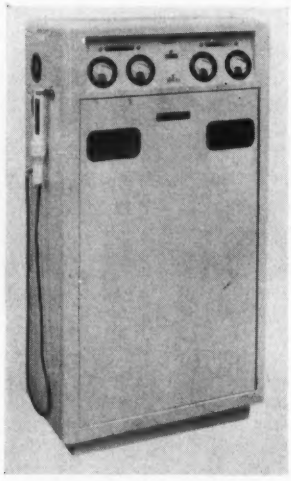
New radiation monitor by Avo, model 1 is light, portable and self-calibrating.

For the detection of contamination on personnel engaged in handling radioactive materials, Mullard have developed a new monitor in conjunction with A.E.R.E. The standard version, model L.130, comprises six units, alpha clothing, two alpha hand, two beta-gamma hand and one beta-gamma clothing. Calibration is in terms of M.P.L., one M.P.L. corresponding to alpha hand, 0.001 μC; beta-gamma hand, 0.03 μC; alpha clothing, 0.0001 μC/cm²; beta-gamma clothing, 0.001 μC/cm². Each unit has a meter and warning lamp with additional audible indication in the case of the clothing units. The complete four-station equipment is 5 ft. 5 in. long, 15½ in. deep and 5 ft. 3 in. high, and is suitable for back-to-back or wall mounting.

1045 ★

A second new hand and clothing monitor, type 1, by E.M.I. Electronics, has been designed to indicate accurately and precisely the presence of radioactive contamination. Both sides of the two hands are monitored simultaneously for alpha and beta contamination by means of four scintillation counters. The alpha clothing probe consists of a scintillation counter feeding a logarithmic ratemeter while the beta-gamma probe uses a halogen-quenched G-M tube.

1046 ★



Hand and clothing monitor (E.M.I. Electronics).

For schools, Labgear offer a beta-gamma radioactivity indicator kit, D.1437. The components can be assembled by post-certificate science students and the instrument is sufficiently sensitive to give a reading from normal background and radiation from a luminous watch dial.

The design uses a robust civil defence type of G-M tube, polarized from a mains power rectifying and stabilizing unit. Geiger pulses are fed into an elementary count rate circuit and displayed on a microammeter. A neon flasher or an audio indicator can be included in the circuit.

1047 ★

A pocket dosemeter has been introduced by Baldwin Instruments. It comprises a small ionization chamber for measuring x and gamma radiation. The chamber is used in conjunction with a charging and measuring device known as the protection electrometer. Full-scale deflection is obtained for 200 mr/hr, i.e., twice the daily tolerance.

1048 ★

Ericsson Telephones survey meter, type 125A, is a small lightweight portable instrument designed for geological surveying and prospecting for radioactive ores. It also has many other applications in nucleonics where a handy portable instrument is required for gamma-ray detection. By using transistorized circuits, and a light but very robust Fibreglass case, it has been possible to reduce the overall size of the instrument to 7½ in. by 3½ in. by 1¾ in. (191 mm by 89 mm by 44 mm), its total weight inclusive of batteries being only 1½ lb. (0.68 kg).

1049 ★

Type 145A alpha, beta and gamma monitor by Ericsson Telephones.

Isotope Applications

There are many different types of nucleonic thickness gauge on the market today. For example, the N563 gamma backscatter gauge by Ekco Electronics is designed for measurement of steel thickness where only one side of the sample is accessible, for example, steel pipes. When gamma rays pass through steel a certain number are deflected by Compton scattering, some being scattered through 180°. During this process they lose energy to the extent of twice the Compton wavelength. If cobalt 60 is the source, backscattered radiation will return at 200 keV. The unit has, built into it, an E.H.T. supply for the photomultiplier tube and suitable time constants to remove random fluctuations on the indicating meter. The instrument will measure up to 1-in.-thick steel.

Another Ekco unit, the N582 auto-standardization gauge, has a retractable scanner which is automatically withdrawn from the sheet at half-hourly intervals to correct any errors arising from source decay or contamination of the source and window by deposition of dust. The balance and sensitivity of the amplifier are checked and corrected as necessary during each standardization cycle. Automatic scanning facilities allow investigation of the material across its width at predetermined positions, while warning of breakdowns or failure to operate correctly is given by a fault alarm system.

1050 ★

A versatile form of thickness gauge has been developed by Burndept. It comprises a ratemeter matched to a

detector chosen for a particular application. If, for example, a scintillation counter is used to detect beta radiation, a source of low activity can be employed thus ensuring a large margin of safety for the operator.

1051 ★

Ekco single channel thickness gauge N 565.

The Vibron Gamma-ray Electrometer by Electronic Instruments used in conjunction with a gamma-ray gauge measures the concentration of uranium ore in a slurry flowing through a steel pipe in an ore treatment plant. A variable back-off control cancels the background so that small signal changes can be observed on the lower ranges.

1051 A

The Firewire inspection equipment developed by Isotope Developments in collaboration with Graviner Manufacturing Co. employs a beta transmission technique to show that there is no discontinuity in the semi-conductive layer within a coaxial element. Firewire is extensively used to give warning of fire in aircraft engines.

1052 ★

Four-channel Atomat thickness gauge (Baldwin Instruments).

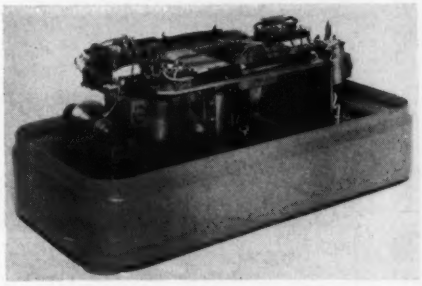
Nucleonic thickness gauges often have to be designed to meet the specific requirements of a particular industry. Recently Baldwin Instruments built a four-channel gauge for the tyre industry. Four electronic continuous balance strip chart recorders measure thicknesses of the order of 1/200 in. Using the continuous balance principle in conjunction with a β source, variations can be indicated and recorded either as material thickness or as weight per unit area. The instrument is actually installed on a machine producing rubber-coated cord for pneumatic tyres. Two channels measure the thickness of the coating on each side of the cord.

1053 ★

Hendrey Relays are now manufacturing under licence from the A.E.A. a borehole logging equipment, Model 1417A. Designed for the location and estimation of radioactive ore deposits or for general stratigraphic measurements at lower radioactive levels the equipment comprises nine separate units. The standard probe contains a gamma-sensitive Geiger counter and feed circuit components in a stainless steel sheath. A probe of higher sensitivity is also available.

The winch for raising and lowering the probe in the borehole has a capacity of 1,100 ft. of cable and a separate unit records the actual depth of the probe. Readings from the probe can be obtained from a battery-powered ratemeter operating in conjunction with a recorder.

1054 ★



Simple computer (Evershed and Vignoles).

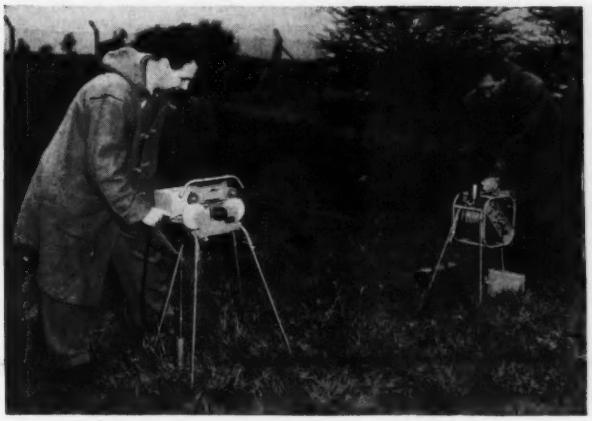
Test Equipment

A wide variety of pulses suitable for testing and adjusting amplifiers, ratemeters, and scalers is provided by the G100B pulse generator by Panax Equipment. Facilities include repetition rates of 1,000, 200, 20 and 2 c/s or triggered by outside signals; 50 V positive or negative pulses to synchronize or trigger an oscilloscope together with variable amplitude and variable width pulses and double pulses with variable spacing.

1055

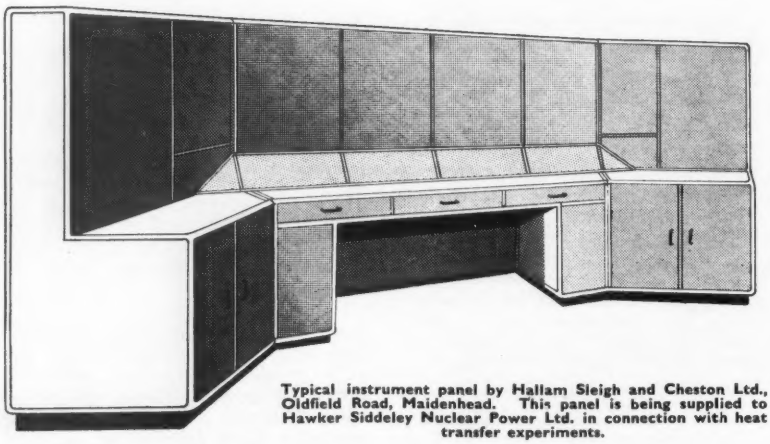
An interesting general-purpose pulse generator by Dawe Instruments is the 412B, providing rectangular pulses of variable duration amplitude and recurrence frequency. Repetition rate is controlled by a free-running blocking oscillator at 12 discrete frequencies, from 25 c/s to 100 kc/s. Alternatively, the blocking oscillator can be triggered from an external signal over the range 15 c/s to 100 kc/s. A monostable multivibrator determines the pulse duration which is continuously variable from 0.3 microsecond to 60 milliseconds in five ranges. An output pre-amplifier provides positive and negative pulses, variable in amplitude up to 20 V.

1056 ★



(Above) D.C. valve voltmeter-microammeter (Nash and Thompson).

(Left) Borehole logging equipment, type 1417A (Hendrey Relays).



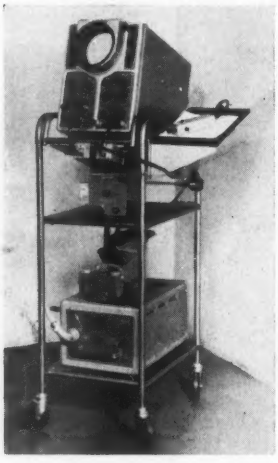
Typical instrument panel by Hallam Sleigh and Cheston Ltd., Oldfield Road, Maidenhead. This panel is being supplied to Hawker Siddeley Nuclear Power Ltd. in connection with heat transfer experiments.

A small d.c. valve voltmeter microammeter by Nash and Thompson is suitable for the measurement of voltages from 0.05 V to 1,000 V with an input impedance of 10 megohms and currents from 10^{-8} to 10^{-4}A at high impedance. Centre zero and balance-to-earth facilities are provided: the accuracy of most ranges is better than 3% f.s.d.

1057 ★

Southern Instruments' M971 oscilloscope has a 3-in. flat-faced c.r.t. The viewing hood and graticule can be quickly replaced with a recording camera. The γ amplifier has a maximum sensitivity of 0.2 V/cm and a bandwidth from d.c. to 80 kc/s. Input voltage range is 2, 6, 20, 60, 200 and 600 V with voltage calibration accurate to $\pm 5\%$.

1059 ★



Nagard oscilloscope, model DE 103 A.

A high-speed oscilloscope, model 301 by Nagard, provides calibrated sweep times from 10 sec to 0.1 μsec over 10 cm, including a calibrated sweep expansion of $\times 10$. The time base is of entirely new design, providing versatile triggering facilities, very linear sweeps under either single-stroke or repetitive conditions, and easy reading of time calibrations. An a.c. pre-amplifier with gain of 100 gives an overall bandwidth from 3 c/s to 40 kc/s. The time base has three modes of operation: triggered, single-stroke and beam trigger. Sweep durations are from 0.3 to 1,000 milliseconds, calibrated in time. The X amplifier has a bandwidth from d.c. to 80 kc/s and maximum sensitivity of 0.6 V/cm.

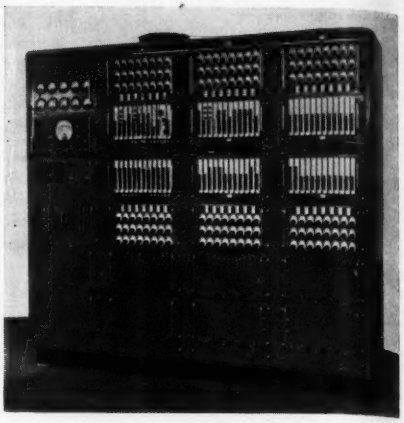
1058 ★

Marconi transportable industrial X-ray equipment.

Suitable for laboratory, workshop or field use, the latest Marconi industrial X-ray equipment is rated at 160 kVp. The set comprises twin H.T. generators, a tubehead and a control unit; an oil cooler is available for the higher tube ratings.

1060 ★

Of the two spectrometers recently developed by Metropolitan Vickers Electrical, one, MSSL, is for the detection of gas leakages in pressurized or vacuum systems whilst the other is for the observation of nuclear magnetic resonance in liquids under conditions of high resolution. The sensitivity of the MSSL is such that it will detect leaks corresponding to the passage of 1 cu cm (at atmospheric pressure) in 30 years. The basic part of the other spectrometer comprises an electromagnet with its



Analogue computer by Fairey Aviation.

associated power supply which provides a magnetic field continuously variable up to at least 15,000 gauss. The electromagnet has 9-in. dia pole caps, optically polished, and the standard gap width is $1\frac{1}{2}$ in. The sample to be examined is inserted in a probe which consists of a cross coil system, the resonance signals being observed according to the Bloch technique. The radio frequencies used are derived by multiplication from a basic 5 Mc/s crystal-controlled oscillator.

Other companies who have recently introduced new nuclear magnetic resonance spectrometers include Fairey Aviation and Mullard.

1061 ★

The new d.c. amplifier introduced by Short Bros. and Harland is capable of solving second order differential equations. The unit comprises four amplifiers and a number of computing equipments. By adding further units a full-scale computer can be assembled.

1062 ★

The Elliott reactor simulator ND181, primarily for the instruction of nuclear engineers, has been designed to represent the operation of a nuclear reactor under a wide range of conditions.

The unit is constructed in the form of a reactor control desk on which indications of power level, control and safety rod positions, etc., are displayed. Pile parameters representing various constants dependent upon fuel and moderator may be chosen by the operator to simulate a number of types of reactor.

The power output from the neutron kinetics computer is displayed upon a Bristol's Dynamaster potentiometer recorder, this reading being continuously computed from neutron density, source strength, and reactivity. The unit may be operated manually or use may be made of two automatic control systems, one an on-off system and the other a proportional system. Trips are incorporated to shut down the reactor should either the power level or period pass through adjustable limits.

1063 ★

Technical Papers and Publications

THE INSTITUTE OF MARINE ENGINEERS

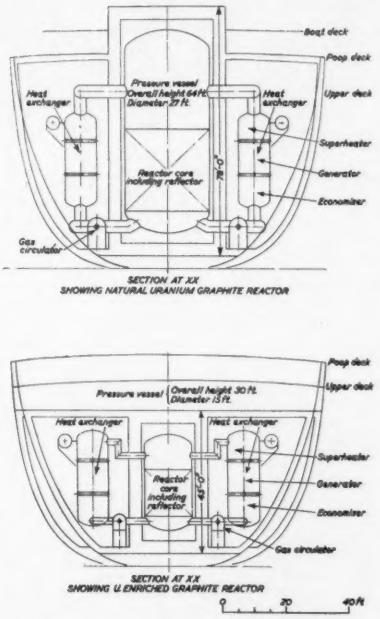
(Joint Nuclear Marine Propulsion Panel)

Propulsion of Ships by Steam Turbine Machinery. By T. W. F. Brown, D.Sc., S.M. (Director, Pametrada Research Station).

Originally presented as the De Laval Memorial Lecture in Stockholm, this paper covers, in reality, two distinct yet allied subjects. The consideration of the future development of steam turbine machinery leads to the examination of the nuclear propulsion of ships, with particular reference to large tankers, and this subject occupies quite a large portion of the paper.

Pointing out that, of the wide field of reactors proposed, only three power reactor technologies have been fully developed: the gas-cooled graphite moderated (Britain), the light water moderated and cooled (U.S.A.) and the graphite moderated water cooled (U.S.S.R.), the paper proceeds to consider other possibilities, with both natural and enriched uranium fuels.

The shielding question, it is pointed out, requires a great deal of research but approximate figures have been worked out for composite shields of lead, steel and water, and it is suggested that the weight of a concrete shield could be cut down by a factor of 0.73 although it is thought that the volume reduction would be considerably more.



Cross sections showing comparative sizes of plant for natural and enriched fuel.

Several alternative designs have been worked out on the basis of a 22,000 s.h.p. installation for graphite moderated gas-cooled reactors based on Calder, for four different fuel enrichments; for a PWR type based on Shippingport (an alternative 10,000 s.h.p. design has been worked out for this type) and for a proposed gas cooled heavy water moderated reactor. The figures are the results of the author's own studies and are abstracted in the accompanying table.

In an appendix, approximate costs have been worked out for a 60,000-ton 22,000 or 44,000 s.h.p. installation.

Assuming two alternative credit figures for plutonium, (a) £5, (b) £10 per gram, net of processing cost, the costs per s.h.p. hour for a 22,000 s.h.p. natural uranium gas cooled unit are (a) 0.73d; (b) 0.61d; the corresponding figures for a PWR enriched fuel unit are (a) 0.67d; (b) 0.58d. For the alternative 44,000 s.h.p. unit the comparable figures are: natural uranium gas cooled, (a) 0.41d; (b) 0.29d; while PWR enriched figures are (a) 0.46d and (b) 0.37d.

Comparison of Reactor Types.

Type of Reactor		Gas-cooled graphite mod.				PWR		Gas-cooled D_2O mod.
Fuel enrichment		Nat.	1.27 Co	1.54 Co	2.0 Co	1.5 Co	4 Co	Nat.
Heat output	MW	68.5	68.5	68.5	68.5	71	36	77
Net output	s.h.p.	22,000	22,000	22,000	22,000	22,000	10,000	22,000
Cycle efficiency	%	24	24	24	24	23	21	21.2
Uranium	tonnes	65	28	16	8	30	8	12
Graphite	tonnes	300	130	75	37	—	—	D_2O 19
Rating	MW/tonne	1.05	2.45	4.3	8.6	2.35	4.5	6.5
Reflector	ft	3	3	2.75	2.5	—	—	18 in graph 4 in D_2O
Core diameter	ft	20	15	12.5	10	5.5	4	8
Core height	ft	20	15	12.5	10	5.5	6	11
Press. vessel diameter	ft	26.5	21.5	18.5	15.5	7.5	6	14.5
Press. vessel height	ft	64	40	36	30	26	25	28
Press. vessel thickness	in.	3	3	3	4	7	6.5	4
CO_2 pressure	p.s.i.	200	270	300	450	—	—	400
Water pressure	p.s.i.	—	—	—	—	2,000	2,000	—
Inlet temperature	°F	460	460	460	460	520	520	375 (M) 400 (Be)
Outlet temperature	°F	680	680	680	680	556	556	800 (M) 950 (Be)
Gas flow	lb/sec	1,160	1,150	1,145	1,136	—	—	620
Water flow	lb/h	—	—	—	—	5.5×10^6	3.5×10^6	—
Pressure drop	p.s.i.	—	—	—	—	100	100	—
Blower power	kW	1,000	920	850	720	—	—	1,600
Pumping power	h.p.	—	—	—	—	1,070	590	—
Steam pressure	p.s.i.	460	460	460	460	560	560	400
Steam temperature	°F	650	650	650	650	d.s.	d.s.	750
Shield weight (concrete)	tons	6,742	4,102	3,272	2,486	1,350	1,200	2,400
Shield weight (composite)	tons	4,800	3,300	2,500	2,000	1,000	860	1,800
Total reactor weight	tons	674	327	227	168	137	40	141
Heat exchanger piping and blower	tons	270	314	332	426	162	90	394

THE INSTITUTE OF FUEL

Nuclear Power Development: Some Experiences of the First Ten Years. By Sir Christopher Hinton, K.B.E., F.R.S. (The 1957 Melchett Lecture.)

The Risley organization commenced operations on February 4, 1946, when the author, with a staff of 18, took over an office block of the Risley Filling Factory, commissioned to build a graphite-moderated reactor for the manufacture of plutonium, a plant for manufacturing fuel elements, and a chemical extraction plant.

An interesting feature of the Risley organization was that one of the first sections of the engineering department was devoted to standardization, so that engineering standards were available from the outset. This has immensely simplified the problems of design, supply and stockholding, and has contributed largely towards financial, as well as technical efficiency.

The passing of the McMahon Act, thus withholding U.S. technological information, had actually proved a blessing in disguise; it rendered it imperative to think for ourselves and had, in fact, resulted in the production of results that had led to our present position of leadership.

It was a mistake, however, to imagine that the story of nuclear energy in Britain was one glorious story of success, and a

number of difficulties encountered were dealt with. By the August of 1946 the staff had grown to 142, with another 101 by the end of the year, yet it had only been possible to recruit one or two engineers with experience of chemical plant design, and it had been necessary to institute a series of weekly lectures on the subject. Practically every detail of the plant had had to be designed " on a clean sheet of paper "; there were no files of details of earlier plants to refer to, although a file of drawings purchased from I.C.I. had relieved this position. High tribute was paid, incidentally, to I.C.I. for the pioneer work they had carried out, particularly on chemical separation plant and on the manufacture of uranium metal.

The outside observer, listening to this paper, could hardly fail to be impressed with the successful outcome of many projects which had been designed on what would normally be considered ridiculously inadequate information, e.g., the bank of large filter presses ordered on the basis of a sample of sludge in the bottom of a 4-oz. bottle, also the fact that the Harwell pile was completed within a few days of the date scheduled on the programme that had been laid down only four days after the Risley department had been scheduled.

The paper contained a note of warning, however, that the long story of success of the A.E.A. as a whole should not be allowed to go to people's heads; that the growing strength of the A.E.A. did not, paradoxically speaking, prove to be its weakness. Sir Christopher concluded:—

" One must, however, be careful that this growing strength of the Atomic Energy Organization does not prove to be its weakness. The rapid advances which we made in the early years were achieved because we were skilful in judging how to navigate difficult waters. We had to press on because only by doing so could we hope to meet the target date for the production of plutonium. If we were wrong we might fail to meet that date, but if we waited till all was clear there was no hope of meeting it.

" As an organization grows in maturity and in size, this approach should become less necessary, but it inevitably becomes less possible. As an organization becomes anchored to an immense capital investment there is a growing danger that the load of its financial responsibility will stifle its initiative. This can only be avoided by careful and intelligent planning of the research and development programme. Research, development, and large-scale trial must move sufficiently in advance of the industrial programme to enable progress in this last to be made without accepting financial risks which are of such magnitude as to make it impossible to justify them."

" **Magnesium** " (February, 1958, p. 52)
We are informed by the author that in Table A7 on the Data Sheet, the value of thermal conductivity for alloy A12 at 300°C should be 0.311, and not 0.301 as stated. Also, in Fig. 13, the two ZW1 curves (Nos. 1 and 2) had not reached fracture and the symbol F should not appear.

THE INSTITUTION OF CIVIL ENGINEERS

The Further Developments of the United Kingdom Nuclear Power Programme. By Sir John Cockcroft, K.C.B., C.B.E., F.R.S. (The James Forrest Lecture.)

In his second James Forrest Lecture (the first was delivered in 1955) Sir John Cockcroft outlined the improvements that had been made to the original Calder design in the commercial nuclear power stations. Operating experience at Calder has been of considerable value and has allowed confidence to grow in the magnox fuel element. During the first twenty-seven months of operation of No. 1 reactor, only three fuel elements developed slight faults. A characteristic curve of activity release for such a fault showed a steady increase in activity leading to five times the background in the B.S.D. detectors after 24 days. Such a slow increase allows extraction of an element to be timed in with routine shutdown. Commenting on the general technology of the gas-cooled graphite moderated reactor, he described experiments in BEPO to determine the concentration of CO in CO_2 that could be expected under power station conditions. In the loop experiments, concentration rose to 0.5%, decreasing after the third start-up to 0.2%. Considerable work had been done on the increase in the transition temperature to be expected in

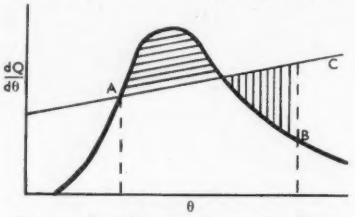


Fig. 1.—Rapid temperature rise from A to B; equilibrium conditions established when shaded areas are equal.

pressure vessel steels as a result of irradiation. Typical results showed an increase from −30°C to 40°C after an exposure of 2×10^{19} n/cm².

Sir John was able to include in his lecture a report on the Wigner release conducted on BEPO on March 15. The difficulty of this procedure can be seen by reference to Fig. 1. At a given temperature (A) the energy release per unit temperature rise is greater than the equivalent specific heat and as the conditions are substantially adiabatic, the temperature of the graphite rises sharply (to B) until new equilibrium conditions are established.

A new method of carrying out this release was adopted at Harwell. The inlet air flow to the reactor was reduced to about 5% of full normal flow and was heated by 750 kW of heating grids installed in the inlet duct. This heated the air entering the reactor to a temperature rising to 130°C. The graphite structure was thereby heated up slowly over a period of ten hours to about 90°C. At this point a slow release of stored energy began and the temperature of the graphite rose, reaching a maximum of 330°C as against a predicted maximum of 370°C. During this period some

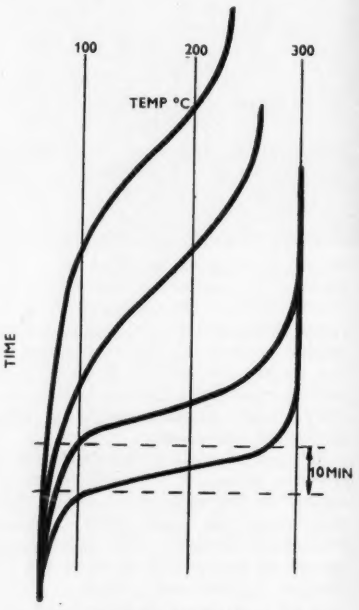


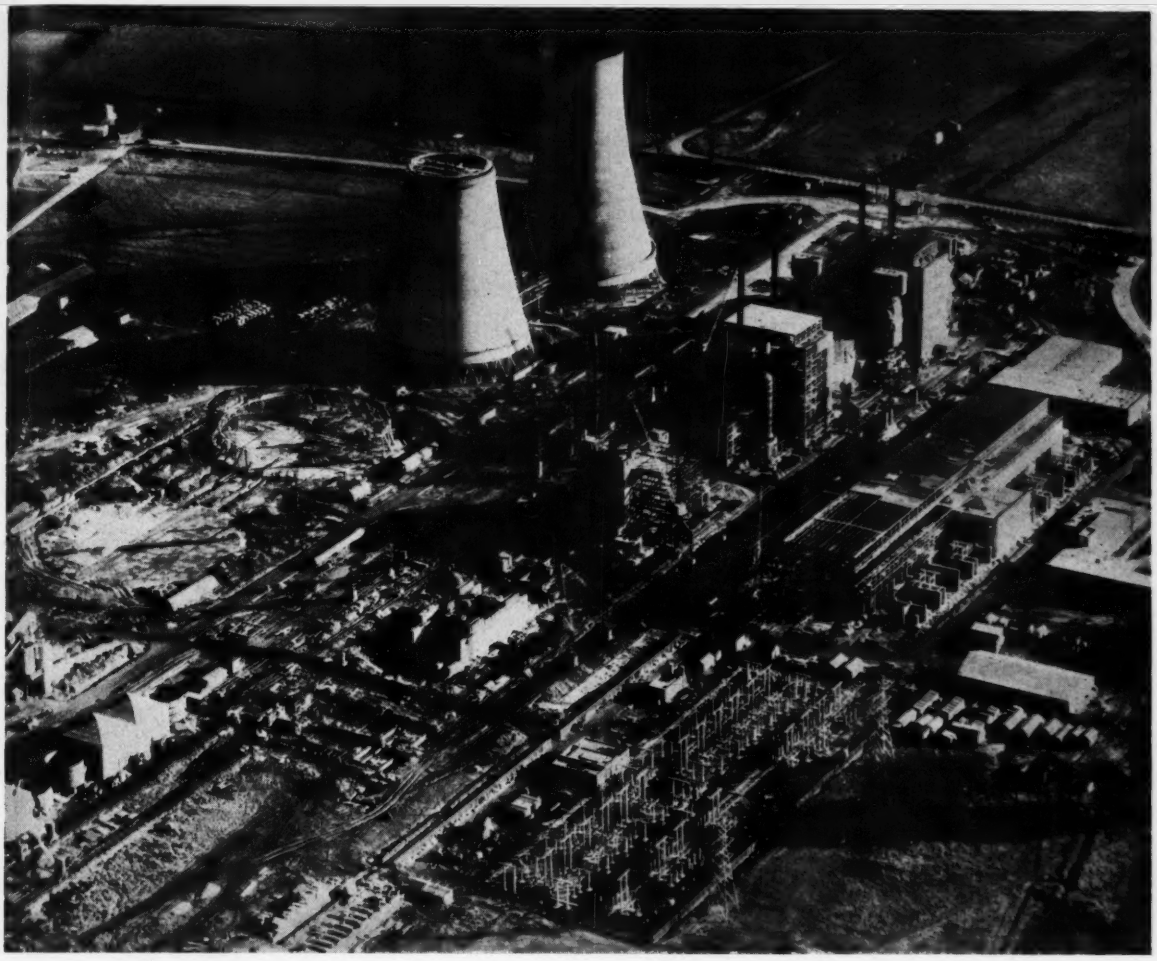
Fig. 2.—Characteristic Graphite temperature rise at four points along a channel.

blocks of the graphite were seen to rise sharply in temperature by about 200°C in a time period of the order of five minutes. The general picture of the graphite temperature rise along a particular channel is shown in Fig. 2.

The zone in which the stored energy release is taking place spreads slowly from the air inlet end of the reactor to the exit end and to other radial regions. The whole operation on BEPO was controlled by a battery of 74 recorders, and a staff of 75 engineers and scientists was engaged in the recording working in three shifts.

The reactor could at any time have been blown cold by turning on the main circulating fans. The close similarity of the experienced results and those anticipated shows that a Wigner energy release can be carried out with complete safety when it is fully instrumented.

Comparative prices of PWR and the Calder type were mentioned followed by a discussion of the AGR project and the gas-cooled heavy water system (see page 140). Sir John concluded by suggesting to the Institution that there was no reason why its members should not be prepared to take a greater overall responsibility in the design and construction of reactor power stations, rather than concerning themselves solely with the civil engineering.



This aerial view, photographed a few weeks ago, shows the progress made at Chapel Cross nuclear power station. The reactors and turbine hall are basically similar to those at Calder Hall, although the station layout is different. Main contractors for the site are the Mitchell Construction Co. Ltd.

World News

International

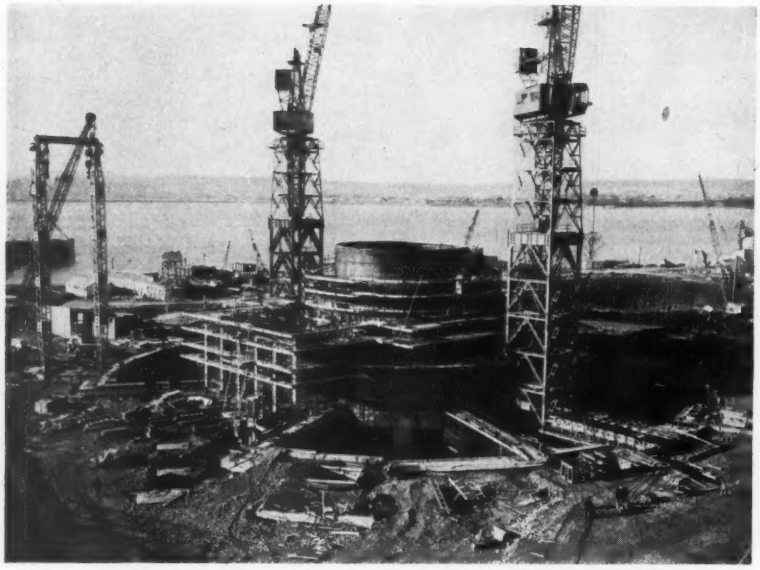
Joint programme of power reactor development between the U.S. and Euratom nations was announced on February 28. A working party will plan the installation in Europe of 1,000 MW of nuclear power reactors. Mr. W. Walton Butterworth, U.S. ambassador to the E.C.S.C., has, in addition, been appointed ambassador to Euratom and the Common Market organization. M. Louis Armand, president of Euratom will be visiting Washington during April for talks with Mr. John Foster Dulles and Admiral Lewis Strauss.

Steering committee of the European Nuclear Energy Agency has decided to invite nuclear scientists and engineers from Europe and N. America to study the O.E.E.C. experimental reactor programme. Particular attention will be paid to the proposal for the joint operation of the BWR at Halden (Norway) and the proposed homogeneous aqueous project at Winfrith Heath. The committee also agreed to work closely with Euratom in respect of public health and safety so that the two organizations could follow the same basic regulations.

Mr. Leo Goodman, nuclear energy adviser to the United Automobile Workers, U.S.A., has recently toured Europe. He discussed objectives for a trade union programme in nuclear energy with O.E.E.C., E.P.A., trade union and government officials.

Broad Agreement on the insurance of risks arising from the operation of reactors was reached at the three-day international atomic energy insurance conference recently held in London. Individual companies agreed to pool their liability on a national basis and, as a general principle, to offer only comprehensive cover for a reactor. The conference endorsed the principle of channelling all liability to the reactor owner. At a subsequent press conference, Mr. A. G. M. Batten, chairman of the British Insurance (Atomic Energy) Committee said that the British pool was currently dealing with applications for the insurance of 17 or 18 reactors.

Governors of the International Atomic Energy Agency began their fourth series of meetings in Vienna on March 10. Most important topics on the agenda are the Agency's fellowship and training programme which is expected to begin this year, and preparation of consolidated health and safety regulations acceptable on an international basis.



The scene at Berkeley in Gloucestershire. This photograph, taken at the end of February, shows the progress made in just over a year on the first reactor.

United Kingdom

ZETA is now in course of reconstruction in an endeavour to increase the maximum temperature to at least 15 million degrees. The main change for the second stage of development of the apparatus will be the addition of a condenser bank to increase the power input and possibly lengthen the time cycle.

BEPO—which has been closed down for three months whilst new instrumentation was installed—underwent a Wigner energy release during the week-end of March 15 to 16. In place of nuclear heating, however, arrangements were made to electrically heat the air intake. Observed results indicate that the operation was entirely successful with the new instruments providing fuller information about the rate of rise in temperature than has been available hitherto.

From all the British nuclear power station sites there is news of good progress this month. At Calder, the third reactor has gone critical well ahead of schedule. The A.E.A. say that the fourth reactor is likely to be commissioned in mid summer this year—some four months earlier than anticipated.

At Chapel Cross, Dumfriesshire, the work is well up to schedule. An accompanying aerial view shows the progress made at the end of last month.

On the newest site, Hinkley Point in Somerset, over 150,000 tons of earth and rock have been moved in three months. Taylor Woodrow have reduced the general level of the sea-front site to 36 ft above sea level. Excavated spoil has been used to reclaim an area up to 250 ft wide and 3,000 ft long.

Latest news from the Bradwell site (Nuclear Power Plant Co., Ltd.) concerns the completion of the 200-ton Goliath crane dealt with in detail on page 167 of this issue.

East Suffolk County Planning Committee has told Central Electricity Generating Board that of five suggested sites for a nuclear power station it prefers The Warren, Sizewell, in Suffolk. Approximately 109 acres of land are available with a beach frontage of 750 yards.

The Advanced Gas-cooled Reactor is now most likely to be built in the Windscale area. Design for a potted-down version of Calder Hall, using enriched fuel, is nearing completion. No definite decision has been made on the actual site although Winfrith Heath and Dounreay have also been considered.

Net estimate for atomic energy in the 1958 to 1959 Civil Estimates is £106 million, an increase of £7.2 million. Grants to the A.E.A. for stores, materials and services for establishments are £17.8 million higher at £28.9 million, but grants for works services, plant and machinery are £9.6 lower at £44.8 million. Loans to the Authority for uranium production are cut by £3.2 million to £1 million.

At Hinkley Point the site has been cleared and work has started on the foundations of the first reactor. Here an 18-in. section is being loaded into the bucket of a Caterpillar Traxcavator for transportation to the shore end of a reactor drain.

S. Africa

Inaugural meeting of the Cape Nucleonics Society took place recently. One of the objects is to help in the establishment and maintenance of an institute for nuclear research by co-operating with the joint committees of Cape Town and Stellenbosch universities.

Austria

Atomic Energy Study Group has proposed that a research and training centre equipped with a 5 MW swimming pool reactor should be established at Götzendorf, on the site of an old aerodrome about 10 miles east of Vienna. The decision on tenders for the supply of the reactor is expected shortly.

Australia

Achievements of ZETA could be considerably improved by using a homopolar generator, Professor Marcus Oliphant, director of the Research School of Physical Sciences at the Australian National University, has said. The homopolar generator at the University is specially designed to produce large pulses of current. Four 19-ton M.S. discs are spun at 900 r.p.m. between the poles of a 12-ft dia magnet. Peak currents of over 1 million amp. can be taken from the discs through jets of sodium or sodium-potassium alloy.

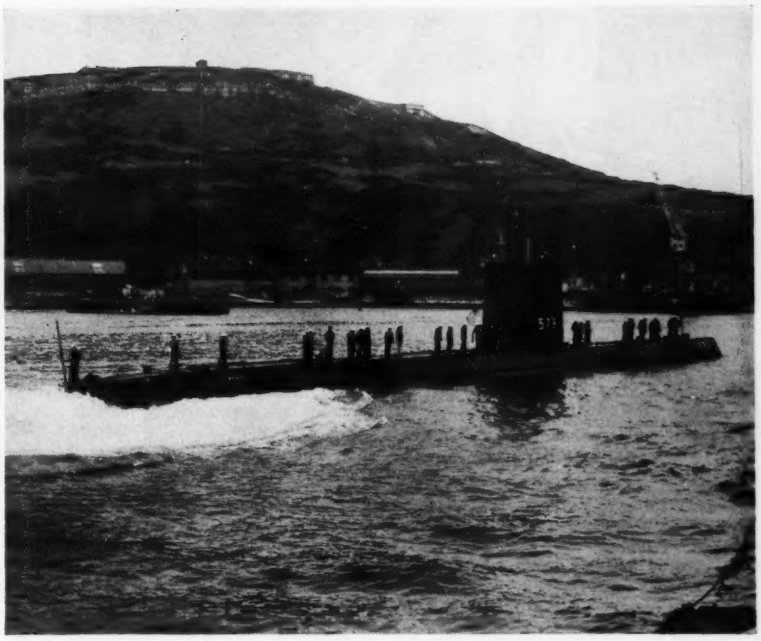
Canada

Canada and Switzerland have signed an agreement for co-operation in the peaceful uses of atomic energy. The agreement permits Eldorado Mining to sell uranium in Switzerland.

NRU made history on February 27, when it became the first reactor to be refuelled while in operation. Under direction of the superintendent, Gib James, the uranium fuel rods were successfully changed. NRU became critical on November 3 last year and has been undergoing a series of tests before being put into routine operation.

Dominican Republic

Santo Domingo University is holding a full-time course on the peaceful uses of nuclear energy. Some fifty students are taking part in the five-months course, which is intended to give basic knowledge to enable them to attend specialized centres abroad.



On March 5, America's latest nuclear submarine, "Skate," arrived in Portland harbour, Dorset, after a shakedown cruise from New London, Connecticut. "Skate" is 319 ft. long and displaces 3,180 tons.

Greece

U.S. Government will contribute $350,000 towards the research reactor in course of construction near Athens. The reactor is a 1 MW heterogeneous, pool-type being manufactured and assembled by A.M.F. Atomics, of New York. The fuel element is being fabricated by Babcock and Wilcox. Total cost of the reactor and associated facilities is estimated at $1.27 million.

India

A new company has been formed to build the fertilizer factory at Nangal Township, Punjab. The company is Nangal Fertilizer and Chemical (Private) Ltd., 157-48 Diplomatic Enclave, New Delhi. The factory is scheduled to produce 3,200 tons of diluted ammonium nitrate (20.5% N); 1 ton of heavy water and 12,000 tons of oxygen per year.

India's first uranium processing plant at Trombay, near Bombay, will begin to operate before the end of the year, Mr. Pandit Nehru, Prime Minister, announced on March 18.

Italy

World Bank has granted a loan of $75 million to Cassa per il Mezzogiorna, a government agency for industrial agricultural and electric power development in Southern Italy.

Japan

Following protracted consultations with the U.K.A.E.A., Board of Trade, Central Electricity Generating Board and the main nuclear consortia in Great Britain, the Japan Atomic Power Co. has asked three of the consortia to submit tenders for a 150 MW single-reactor nuclear power station. The groups concerned are A.E.I.-John Thompson, English Electric-Babcock and Wilcox-Taylor Woodrow, and G.E.C., Simon-Carves. The Nuclear Power Plant Co. declined to tender. Although the details of the Japanese specification have not been published, the final design of station must be earthquake resistant and an emergency shut down system will have to be developed. The delegation also declared that as much of the station as possible would have to be manufactured in Japan. The tenders are to be submitted by July 31.

On his return to Tokyo on March 12, Mr. Daigoro Yasukawa, chairman of the company, and leader of the negotiating group, said that the company anticipated the cost of electricity would be 4½ yen (about 1d.) per kWh.

Korea

Minister of Reconstruction, Song in Sang, is reported to have proposed at a meeting of the Combined Economic Board that Korea should build a full-size atomic power plant. Korea already has an agreement with the U.S. for the supply of enriched uranium. The United Nations Command Economic Co-ordination for Korea has said that "atomic power in Korea is still far off" and has urged that the present electric power system should be placed on a self-supporting basis before nuclear power is adopted.

Pakistan

Uranium deposits with a high yield have been discovered in the Hazara district of the N.W. Frontier province, Dr. Nazir Ahmed, chairman of Pakistan A.E.C., announced in Lahore.

U.S.A.

An opinion poll on national policy has recently been conducted by the Atomic Industrial Forum. One hundred and sixty-one organizations were questioned concerning their views on atomic energy policy. Of these, 69% were in favour of an expansion in U.S. nuclear power developments, 24% indicating that developments should be maintained at present levels; 62% also proposed that the expansion should be formalized by a new national policy programme. There are diverse opinions upon the way expansion should be carried out, but a general requirement was for indemnification against third-party liability, guaranteed prices for enriched uranium and plutonium and further declassification of information. It would appear that a five- to ten-year programme is envisaged with something like 3 million kW as a reasonable installed capacity. This would involve a government expenditure of between $1,000 million and $2,000 million. The wide divergence of opinion on reactor types could be roughly broken down into order of preference as (1) light water cooled and moderated; (2) fast breeder; (3) gas cooled.

The gamma irradiation service of the A.E.C. will be discontinued as from March 31. A recent survey has shown that at least 16 academic and industrial organizations are prepared to provide a gamma irradiation service on a commercial basis and can satisfy the needs of the country. A number of facilities have sources of more than 1,000 curies of Cobalt-60.

Reactors overseas should form part of the U.S. power demonstration programme according to a proposal made by Dr. Chauncey Starr, vice-president of North American Aviation Inc. In a bid to accelerate the U.S. Programme, and at the same time break into overseas markets, Dr. Starr suggests that development plant should be built abroad with or without the direct co-operation of the country involved, and arrangements then made for the plant to be purchased by the country at a price similar to that paid for conventional plant. In addition, the United States would provide fuel elements for the operation of such plant for an extended period and would maintain ownership of the fuel, selling to the users the heat produced. It is claimed that such an arrangement would satisfy the two objectives of extending the power demonstration programme and of introducing atomic energy into power deficient countries.

Overall cost of the Shippingport PWR totalled $121.4 million according to final figures of the three principals involved. Westinghouse Electric Corp., who built the PWR and supplied much of the equipment put up $500,000; Duquesne Light Co., operator of the plant paid $22.5 million and the U.S.A.E.C., $98.4 million. Included in the total is some $48.9 million for research and development. Based on a power output of 60 MW the cost per kWh is 64 mills. When the ultimate power level is raised the cost will be lower.

Pacific Gas and Electric Co. proposes to build a 60 MW nuclear power plant beside its existing thermal plant at Humboldt Bay, North Carolina. General contractor will be Bechtel Corp.; a General Electric BWR using 2% enriched uranium oxide will operate at 1,000 p.s.i. and about 545°F. Estimated power cost is 8.7 mills per kWh.

U.S.S.R.

New research reactor at the nuclear physics institute of the Kazakh Academy of Sciences will be used for the production and investigation of radioactive isotopes with very short periods of life.

Personal

Mr. R. N. Millar.

Dr. K. J. Wootton.

Mr. Pierre Huet.

Appointments

Mr. Hector McNeil, B.E., M.I.Mech.E., M.I.E.E., F.Inst.F., as managing director, Babcock and Wilcox Ltd., in succession to **Sir Kenneth Hague,** M.I.Mech.E., M.I.E.E. Sir Kenneth remains deputy chairman of the company.

Mr. J. Stewart Robertson, general manager, Babcock and Wilcox, as a director to fill the vacancy created by the retirement of **Mr. C. H. Sparks.** Mr. Sparks continues in his present capacity as engineering consultant to the company.

Mr. R. N. Millar, manager of the G.E.C. Atomic Energy Division, becomes general manager of the company's Fraser and Chalmers Engineering Works. He will still be responsible for the company's nuclear energy activities. **Dr. K. J. Wootton** succeeds Mr. Millar as manager of the G.E.C. Atomic Energy Division.

Mr. A. E. Grimsdale, B.Sc.(Eng.), formerly manager, home sales, as director and commercial manager, Metropolitan-Vickers Electrical Co. Ltd.

Mr. John Albertini, one of the chief sales executives of Ruston and Hornsby Ltd., assumes responsibility for the development of new markets for Ruston products, including small nuclear power stations of 2 to 25 MW capacity.

Dr. John Douce of Manchester University has been retained by Seromex Controls Ltd. as consultant on theoretical problems arising in the field of non-linear control systems and systems subject to random fluctuations.

Mr. L. F. Miller, deputy chief contracts officer of the Central Electricity Generating Board, as chief purchasing and contracts officer of the Board.

Dr. P. H. Sykes, a director of the British Oxygen Co. Ltd., as chairman of the low-temperature group of the Physical Society.

Mr. Badr El Din Hamdi, at present deputy director-general, Ministry of Finance for the Government of Egypt, to be director of the division of finance, International Atomic Energy Agency.

Prof. Dr. Joseph Esser, at present legal adviser to the German Ministry of Atomic Energy, to be director of the legal division, I.A.E.A.

Dr. Edward Lee as deputy director of the National Physical Laboratory.

Mr. A. W. Page, sales manager, Igranic Electric Co. Ltd., is now responsible for the company's home and export sales organization.

Mr. David C. Nutting, M.B.E., A.R.C.S., B.Sc., A.Inst.P., A.M.I.E.E, as a director of Solartron Industrial Controls Ltd., a member company of the Solartron Electronic Group.

Mr. L. F. Cooke as commercial sales manager, Cambridge Instrument Co. Ltd. **Mr. A. T. Jones** as sales manager of the mechanical thermometer division. **Mr. S. A. Bergen,** M.B.E., M.I.E.E., as chief development engineer.

Mr. J. F. B. Jackson, B.Sc., F.R.I.C., F.I.M., as managing director of A.P.V.-Paramount Ltd. Mr. Jackson has also joined the board of P.I. Castings (Altrincham) Ltd.

Mr. A. McLellan, C.A., deputy accountant of the North West, Merseyside and N. Wales Division, Central Electricity Generating Board, as divisional accountant.

Mr. J. C. Helliar, formerly southern regional representative of Thomas Mercer Ltd., as sales manager of the air gauge division.

Mr. A. Richard Gardner as chief chemist, stable isotope group, 20th Century Electronics Ltd.

Above we reproduce a photograph of **Mr. Pierre Huet,** who, as we announced last month, is the new director of the European Nuclear Energy Agency.

Mr. N. M. Peech as a director of Albright and Wilson Ltd.

Mr. C. L. McAllister as head of the sales promotion department of Airmec Ltd.

Mr. T. P. Rome, D.F.H., A.M.I.E.E., as Liverpool branch manager for British Insulated Callender's Cables Ltd., following the retirement of **Mr. L. J. Fairhurst.**

Awards

Sir Frederick Rebbeck, chairman and managing director of Harland and Wolff Ltd., has been made a Commander of the Order of St. Olaf by the King of Norway.

Tours

Mr. G. H. Black, a director of Kestner Evaporator and Engineering Co. Ltd., is paying a short visit to the United States for discussions with American companies.

Mr. E. N. Shaw, B.Sc., editor of *Nuclear Engineering*, will be visiting reactor stations and various companies engaged in nuclear development in the United States during April.

Retirement

Mr. R. L. Paice, sales director of Igranic Electric Co. Ltd., relinquished his position on March 1. He remains a director and will carry out special assignments of the board.

Obituary

Nuclear Engineering records with regret the death of the following:—

Mr. H. T. Eatwell, joint deputy chairman and managing director of G. A. Harvey and Co. (London) Ltd., on February 20.

Mr. Hector McNeil.

Mr. J. Stewart Robertson.

Mr. A. E. Grimsdale.

Mr. J. H. Albertini.

Mr. A. Richard Gardner.

Mr. T. Tuohy.

Mr. W. R. A. Taylor.

Mr. D. R. Mackey.

Mr. C. R. Tottle.

Industrial Group Appointments

The Industrial Group of U.K.A.E.A. announces the following appointments, all of which relate to existing staff of the Group. Several of these represent a further stage in the strengthening of the staff of Operations Branch, in implementation of the recommendations of the Fleck Committee.

Dr. J. M. Hill, formerly deputy director, technical policy, becomes deputy director of operations (technical) at Risley.

Mr. G. R. Howells, M.B.E., formerly chemical engineering adviser at Risley, as works general manager, Chapelcross Works.

Mr. H. Cartwright, M.B.E., formerly assistant director (experimental reactors) becomes deputy director, industrial power branch at Risley.

Mr. T. Tuohy, formerly deputy works general manager, North West Area, becomes deputy work general manager (reactors), Windscale and Calder Works. He will be deputy to **Mr. H. G. Davey,** the works general manager.

Mr. W. R. A. Taylor, formerly works manager, becomes deputy works general manager at Capenhurst Works.

Mr. C. R. Tottle, formerly head of laboratories at Dounreay becomes deputy director (reactors) there.

Mr. D. R. Mackey, at present head of laboratories at Windscale, will take up the position of deputy works general manager (chemical plants) there at the end of March.

Industrial Notes

William Mallinson and Sons, Ltd., who have just opened a new extension to their offices in Hackney Road, have already made a number of notable contributions to nuclear engineering. For example, the company supplied a large quantity of thermal insulation panels for use at Capenhurst. These panels are faced with 22 s.w.g. aluminium and edged with teak. In some of them provision was made for viewing or remote handling apertures. X-ray insulation panels are included among the wide range of wall materials produced by the company.

Cambridge Instrument Co., Ltd., have appointed B.S.E. Co., Ltd., 149-151 Regent Street, London, W.1, as their agents for Yugoslavia.

C. A. Parsons and Co., Ltd., are to receive an order from the Central Electricity Generating Board for a 550 MW turbo generator, condensing and feed heating plant.

Pritchett and Gold and E.P.S. Co., Ltd., have supplied three large stationary batteries costing £17,000 to Dounreay. For the switching station the company supplied, through A. Reyrolle and Co., a £2,000 battery.

Acheson Colloids, Ltd.'s telegraphic address was incorrectly given in an advertisement in our March issue. The correct designation is Oildag.

Dewrance and Co., Ltd., announce that their subsidiary, Jones Tate and Co., Ltd., will operate as the Jones Tate division of the parent company. Mr. P. F. Gifford has been appointed divisional manager and Mr. A. C. Jones, A.M.I.Mech.E., sales manager.

British Oxygen Engineering Co., Ltd., has been awarded a contract for a plant to purify argon gas at Dounreay.

C. A. Parsons and Co., Ltd., are building new research laboratories costing over £1 million for nuclear research and development. It is anticipated that the building will be completed by the end of this year.

Rank Cintel Ltd. is the new name for Cinema-Television Ltd.

Western Manufacturing (Reading), Ltd., have just opened a new factory on the Millbrook trading estate at Southampton. The factory will provide engineering and electronic manufacturing facilities to meet an A.E.A. contract.

Wandleside Warren Wire Ltd. is the title of a new joint company formed by Wandleside Cable Works Ltd. and its subsidiary, Irish Cables Ltd. and the Warren Wire Co. of New Jersey, U.S.A. The new company will manufacture electric cable at a works in course of erection near Dunmurry, N. Ireland.

English Electric Co., Ltd., have just received an order from the C.E.G.B. for two in-line turbines of 275 MW capacity, for Blyth power station. The contract is said to be worth more than £5 million, including condensing and feed heating plant. English Electric already have a contract for the 5-200 MW machines for High Marnham. The steam conditions at Blyth will be 2,300 p.s.i. and 1,050° F, with reheat.

Kelvin and Hughes (Industrial) Ltd., have appointed Mr. W. Roddis as area representative for the East and West Ridings of Yorkshire, North Lincolnshire and North Derbyshire. Mr. Roddis replaces Mr. J. Illingworth.

Martonair Ltd. announce the appointment of a further technical representative in the North-West. Mr. S. Teasdale has been accredited to South Manchester and an area enclosed by Chester, Crewe and Oldham. Mr. R. G. Barnes will continue to represent the company in the Sheffield area.

Gresham Transformers Ltd. are building a new transformer bay at their Twickenham Road factory.

Ferranti Ltd. announce an average price reduction of approx. 19% on their range of silicon rectifiers.

The Solartron Electronic Group Ltd., and **Ericsson's Telephones Ltd.,** have entered into an arrangement whereby Solartron will have world-wide sales rights (except Scandinavia and S. Africa) for certain Ericsson products.

Firth Cleveland Instruments Ltd. are planning construction of a new 80,000 sq ft factory adjacent to the main Simmonds Aerocessories factory at Treforest, Glam. The new factory will enable the company to expand its range of instruments.

George Kent (Canada) Ltd. is the new name for the Canadian subsidiary company which has previously used the name Kent-Norlantic Ltd.

The Duke of Edinburgh will be patron of the Electronic Computer Exhibition and Business Symposium to be held at Olympia, London, from November 28 to December 4 this year.

The International Organization for Standardization will meet in Harrogate from June 9 to 21. One of the fifteen specialized technical committees will discuss standards for nuclear energy.

20th Century Electronics Ltd. are again extending their factory at New Addington, Croydon. This is the fourth major building project the company have undertaken in the past five years.

William Jessop and Sons, Ltd., are offering supplies of titanium on attractive terms for development projects. The company has installed production melting plant for titanium. A new consumable electrode arc melting furnace which will treble the manufacturing capacity is in course of installation.

B. and K. Laboratories, Ltd., opened their fourth international instrument show at Caxton Hall on March 24. Following the trend established in previous years the company is now acting as agents for an increasing number of instruments manufactured in the U.S. and Europe. Details of equipment suitable for nuclear engineering applications will be given in the May issue of *Nuclear Engineering*.

Mancuna Engineering, Ltd., have been awarded a contract for CO_2 by-pass and drier filters for the Bradwell nuclear power station by C. A. Parsons and Co., Ltd.

Simon-Carves, Ltd., have ordered 20 water feed pumps for the Hunterston station from G. and J. Weir, Ltd. Eight high-pressure electrofeeders of the five-stage ring-section type will each have an output of 447,600 lb/hr at 800 p.s.i. and two auxiliary high-pressure pumps will each discharge 57,250 lb/hr at 772 p.s.i. The main low-pressure pumps are also eight in number to discharge 658,300 lb/hr each at 323 p.s.i. The two auxiliary low-pressure pumps will each discharge 85,000 lb/hr at 264 p.s.i. The main pumps are to have Weir relay-operated automatic by-pass valves to protect the pump in light-load operation.

Hayward Tyler and Co., Ltd., have received from Babcock and Wilcox, Ltd., an order for 48 glandless circulating pumps to be incorporated in the heat-exchanger circuits of Hinkley Point nuclear power station. These pumps are similar to those on order for Berkeley, Bradwell and Hunterston nuclear power stations. The approximate value of the contract is £125,000.

Production Fights Inflation is the theme of the third Production Exhibition and Conference which takes place at Olympia, London, from May 12 to 21. Exhibits will be divided into six sections, one of which will deal with research and development in nuclear engineering and other industries.

New Metals and Chemicals Ltd., and **Flerschmann (London) Ltd.,** have moved to larger premises at Chancery House, Chancery Lane, London, W.C.2. The new telephone number is Holborn 7415 (8 lines).

Richard Crittall and Co., Ltd., have acquired the share capital of Thomas McDowell Ltd. The parent company propose to expand their air conditioning and ventilating manufacturing capacity.

Rocol Ltd. have recently introduced an improved version of their Molytox lubricant. The new product is known as Molytox Plus and it is said to produce a film which resists wear over fifteen times as long as the company's original molybdenised lubricant.

Second Geneva Atomic Conference

The second Geneva Conference on the peaceful uses of atomic energy is being held from September 1 to 13 this year.

The president of the conference is to be Professor F. Perrin of the Commissariat a l'Energie Atomique de France and the secretary-general, Dr. S. Eklund of Sweden.

Arrangements for U.K. participation are being organized by an executive committee (chairman, Sir John Cockcroft; secretary, Mr. B. W. Mott) and a papers committee (chairman, Dr. B. F. J. Schonland; secretary, Dr. T. A. Hall), with a secretariat operating from the Atomic Energy Research Establishment, Harwell. The representatives on the committees have been drawn from the Authority; the Electricity Authorities; Industry; the Medical Research Council; Universities and other organizations.

The papers committee has considered the suitability of a large number of suggested papers and has selected about 200 for submission to the United Nations. This represents about 10% of the total number expected from all participating countries and is approximately the same percentage as in the previous conference in 1955, when the total number was about 1,000. Included in the 200 proposed U.K. papers are eight which deal with fundamental work in the thermonuclear energy field. The approximate distribution of papers is 60% from the U.K. Atomic Energy Authority, 22% from Industry and 18% from the Medical Research Council, hospitals, universities, and so on.

As in 1955, two atomic energy exhibitions will be held in Geneva during the conference. The first of these will be a scientific exhibition under the auspices of the United Nations, at the Palais des Nations. A United Kingdom exhibit, 5,000 sq ft in extent, is being arranged by the Authority. A prominent feature of the U.K. exhibit will be a model of the thermonuclear research apparatus Zeta. The other, which will be commercial, is the International Exhibition on the Peaceful Uses of Atomic Energy, at the Palais des Expositions. The British section, at this latter exhibition, is being organized by the Nuclear Energy Trade Associations' Conference. More than 50 British companies will be exhibiting in this section, which will alone cover more than 30,000 sq ft, and will include an exhibit of 3,500 sq ft by the Authority.

The U.K. delegation is expected to consist of five delegates, about 250 advisers and about 250 observers, the advisers being drawn primarily from among the authors of papers. The leader of the U.K. delegation will be Sir John Cockcroft, member for scientific research of the Authority. The other four delegates are expected to be a second representative of the Authority and representatives of the Royal Society, British industry, and the Medical Research Council. People interested in attending the Conference as observers should apply for passes as soon as possible, and in any case not later than April 19. Representatives from industrial concerns who are working in the atomic energy field should apply to Mr. M. H. L. Whitehouse, Nuclear Energy Trade Associations' Conference, 32 Victoria Street, London, S.W.1, and all others to Mr. J. C. Walker, United Kingdom Atomic Energy Authority, 11 Charles II Street, London, S.W.1.

Meetings

April 1, 1958.—"The Control and Instrumentation of a Nuclear Reactor," by A. B. Gillespie, B.Sc. before a meeting of North Midland Centre, I.E.E. at Royal Station Hotel, York at 7 p.m.

April 9.—"The combined Nuclear/Fossil Fuel Cycle." A discussion organized by the Steam Group, Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, London, S.W.1, at 6 p.m.

April 16.—"Operational Experience—Calder Hall," by K. L. Stretch, M.A. before a meeting of the British Nuclear Energy Conference at the I.E.E., Savoy Place, London, W.C.2, at 5.30 p.m.

April 16.—"Some Structural Aspects of Nuclear Reactors," by W. H. Chilton, A.M.I.Struct.E. before a meeting of the Institution of Structural Engineers, Yorkshire Branch at Central Electricity Authority Offices, Whitehall Road at 6.30 p.m. (Lecture repeated in Sheffield on following day at Royal Victoria Hotel at 6.30 p.m.)

April 17.—"Thermo-Nuclear Developments—Sceptre 3," by S. Kaufman, B.Sc., Ph.D., G.I.P. (A.E.I. research laboratory) at the conference held in conjunction with I.E.A. exhibition, Olympia at 3 p.m.

April 22.—"Operational Experience—Calder Hall," by K. L. Stretch, M.A. before a meeting of South West Scotland, Sub-centre, I.E.E., Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow, C.2, at 7 p.m.

April 29.—"Architectural Problems Relating to the Use of Ionizing Radiations," by G. W. Mullett, M.A. at the Royal Society of Health Congress at Eastbourne at 10 a.m.

April 30.—"The Safe Disposal of Waste from Atomic Energy Establishments," by B. A. J. Lister, M.Sc., Ph.D., A.R.C.S., D.I.C., F.R.I.C., at the R.S.H. Congress, Eastbourne at 10 a.m.

MAY

May 19 to 23.—International Convention on Microwave Valves. Institution of Electrical Engineers, Savoy Place, London, W.C.2.

JUNE

June 11.—Recent developments in nuclear reactor technology will be discussed with representatives from British industry at A.E.R.E., Harwell. Details from The Director (Industrial Liaison Office), Building 329, A.E.R.E., Harwell.

SEPTEMBER

September 1.—Second International Conference for Analogue Computations, Strasbourg. Mr. F. H. Raymond, 138 Boulevard de Verdun, Courbevoie, (Siene), France.

September 16 to 20.—International Symposium on Nuclear Electronics, Maison de l'U.N.E.S.C.O., 2 Place de Fontenoy, Paris, 7. Correspondence should be addressed to: Colloque International Electronique Nucleaire, 10 Avenue Pierre-Larousse, Malakoff (Seine), France.

MAY, 1959

May 25 to 29.—International Convention on Transistors and Associated Semiconductor Services, Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Orbits in Industry

WAY back in January, Tangent recorded an earnest hope that the Press Information section of the Atomic Energy Authority would be a little more get-at-able when they moved into their new home. Hopes, however, were dashed on our first visit. True, reception was more decorative than the messengers in the Ministry of Supply—but just as stony-hearted. Since the building is not yet finished, as is customary nowadays, the photographic library is housed inside the Security section—which comprises everything except the entrance hall. As that pop number of yesteryear would say, Back in the Old Routine. Except, of course, that they have improved upon it; in addition to the form-filling, and the escorting from door to door, one has to wear a ruddy great brass badge. Apparently, although the photographic people will move in about a couple of weeks, the press gang will remain under lock and key, so this solemn farce will have to be gone through each time anyone wants some information.

There may, or may not, be a case for keeping some bits of the A.E.A. out of bounds, but the policy is quite indefensible when applied to the very people who should be most accessible. Let us hope that this passion for playing at cops and robbers—or, more appropriately, commissars and moujiks*—does not spread to the C.E.G.B., the Coal Board, the Gas Council, or any other large organizations, or life will become one riot of form-filling.

What, Never?

In any case, did not Sir Christopher Hinton, in the Institute of Fuel's Melchett lecture, intimate that the A.E.A. had no worth-while secrets withheld from publication? He should look at it from where we're standing.

Well . . . Hardly Ever!

One point in the Melchett lecture, which Tangent otherwise found of absorbing interest, raised a small cynical smile, when we were warned that we must not believe from all the publicity, that the progress of the A.E.A. had been one glorious band-wagon of success. Have we, really and honestly, had much opportunity to hear the other side? This point was raised a couple of months ago when British and American methods were compared.[1] If they drop a clanger, they read a paper about it. In Britain, the situation is rather reminiscent of the legendry chemist attracting the attention of a customer who had left his change behind him. He, you will recall, rapped on the window with a sponge.

Head for Heights?

Never having climbed Nelson's Column (although he did once carry out certain alterations to the adjacent equestrian statue of George III—and that's high enough) Tangent is unable to say from personal experience whether the Bradwell crane is really as high; but it certainly is a lot of crane. Not that he did actually climb the crane itself; about half-way up and that was enough. However transport had been laid on to the top of the tower used for erection of the Goliath, via another crane and a sort of giant tea-tray, with an all-too-small railing round it, so the effect was available without the effort. (Note to those who believed that vibrations from the Diesel was responsible for the tremors in the structure—it was Tangent's knees knocking.)

Centenary 1

Rivalling the Faraday lecture in its elaborate demonstrations, the Siemens Centenary lecture was recently delivered by Dr. J. N. Aldington, chairman and managing director of Siemens Bros. and managing director of Siemens, Edison Swan Ltd., and 2,400 persons attended.

William Siemens, who came to Britain as a young man of 20 in 1843, certainly seems to have been, to say the least of it, a man of parts, and the company he founded did pioneer work in many fields, from telegraphy to traction, and lighting to steelmaking. Since the early 1920s however, when it turned over its heavy machine business to English Electric, the company has specialized in lighting and telecommunications and, incidentally, earned no mean reputation at both. Dr. Aldington was, as usual, exceedingly modest about his own achievements; he gave the argon arc lamp, which has such remarkable colour-rendering properties, its due attention as an important development, but rather as if it had been something that had been developed by somebody else; an attitude that is not so commonplace that it can pass without comment.

Centenary 2

While centenaries of manufacturing companies in the engineering field are rare enough those of individuals are even rarer, and we offer respectful congratulations to Sir James Swinburne, F.R.S., who achieved his on February 28, and has had a career that has not been lacking in incident. One of the leading electrical engineers at the turn of the century, he turned his attention to plastics in the early 1900s and investigated "an interesting but useless novelty," the result of a reaction between phenol and formaldehyde. Two years of research work on production methods and he found that his patent had been anticipated by 24 hours. Otherwise, we might have had Swinburnite instead of Bakelite.

Centenary 6.7

While on the subject of centenaries, what is the oldest commercial company in the world? (That boy at the back there! Wake up!! Next boy! Next! Oh *tell* him, Smithers!) According to the *Inco-Mond Magazine* published by the Mond Nickel Co., Ltd., it is a Swedish metallurgical concern, called Stora Koppaberg Bergslags Aktiebolaget, and it was known to exist in June, 1288. (The information has no practical value, of course—just thought you'd like to know.)

Betas By My Bedside

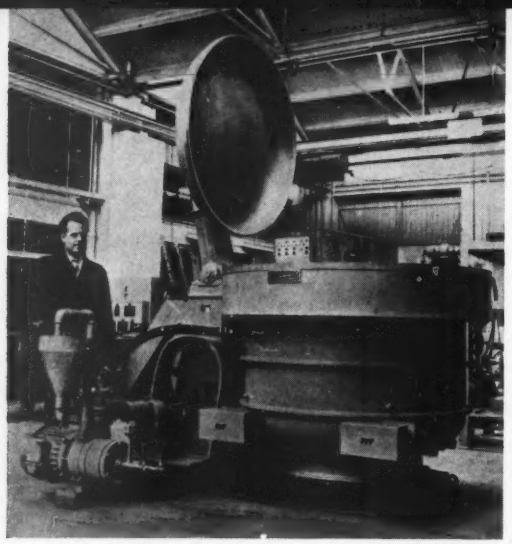
Glancing through the pages of a popular weekly, while waiting his turn for a short-back-and-sides, Tangent was fascinated by a letter from a reader, who had entertained some uneasiness about the harmful effects of a radiation from her luminous alarm clock. A picture of decontamination work being carried out by someone wearing plastic overshoes, however, had convinced her of the excellent radiation-stopping properties of these materials, and the clock now lives in a bag of transparent plastic, thus putting an end to what had obviously been a Great Big Worry. Comment is superfluous, of course—but that won't stop it, anyway.

It really was a frightful shock
When I discovered that my clock
Right by my bedside, standing free,
Was radio-activating me;
Its hands and figures, all ablaze,
Just pumping out the gamma rays.
This menace, though, I could assuage
(Thank Heaven for the Plastics Age!)
And foil the dread Atomic Rain
By wrapping it in Cellophane.
But then—another dreadful fright
I had to wind it—every night!
This chore I managed to attack
All muffled in my plastic mac
So, did I worry?—No, sirree!
Protected well by P.V.C.
Now . . . I'm again with fear
bedevilled
For someone says the glass
is BeV-elled
I wonder . . . Can I sleep
serene
Beneath a sheet of Polythene?
Oh, tell me—Is there any
hope?
Or shall I be an Isotope?

Tangent

* The danger of this can be seen by referring to Tennyson's ("Merlin and Vivien") . . . .
". . . It is the little rift within the lute
That, by and by, will make the moujik mute;
And, ever widening, slowly silence all. . . ."

Processes and Equipment



Large ultrasonic equipment for cleaning components on a fully automatic production basis.

Ultrasonic Cleaning

Where extreme cleanliness of components is essential to a manufacturing operation ultrasonic methods frequently provide an economic answer. An interesting equipment capable of handling comparatively large masses on a production basis is now available from Electro-Chemical Engineering. The apparatus combines ultrasonic cleaning with a vacuum technique. The frequencies used are 400 kc/s and 40 kc/s, and the transducers are piezo-electric and made of barium titanate.

The advantages of the vacuum technique are considerable. With the removal of air from the solvent, cavitation is far more effective, air pockets are removed from any intricate component, thereby enabling the entire surface to have good solvent/surface contact which is essential for good cleaning. Impacted compound in small blind holes is also easily and readily removed by this technique.

The cleaning sequence usually begins with a pre-cleaning operation using perchlorethylene or trichlorethylene with continuous filtration. Then follows the ultrasonic stage with or without vacuum, but with continuous filtration using the same solvent. Next, there is a continuously filtered rinse also using the same solvent, a vapour degrease process, and finally a drying stage which may include the use of vibration, infra-red and a stream of hot, filtered air. All these processes may be incorporated in hand or fully automatic machines.

(Electro-Chemical Engineering Co., Ltd., Woking, Surrey.)

1101 for further information.

Purifying Argon

A mobile argon purification plant designed to purify commercial argon gas both before use and after circulation in process work is now being manufactured by Western Detail Manufacturers. The degree of purification is from 1½ to 2 ppm with a flow rate of 0 to 200 cu ft/hr at 0-5 p.s.i. The main purifying pot will take up to 20 kg of various kinds of gettering agent, and facilities are provided for varying the temperature of the agent up to 850°C.

For removal of oxygen only a fairly low gettering temperature is sufficient; a much higher temperature is necessary for oxygen and nitrogen. A small bleed-off circuit enables all traces of hydrogen to be eliminated.

A typical application of the plant is in purifying argon circulating in glove boxes. At 100 cu ft/hr, 4 W.G., better than 1½ to 2 ppm is obtainable. Dependent on the degree of contamination of the gas the 20 kg of uranium burnings used for gettering would have a life of about three months' continuous use. In some instances, therefore, where continuous circulation is necessary two pots are used with provision for changing from one to another without break in the flow of gas.

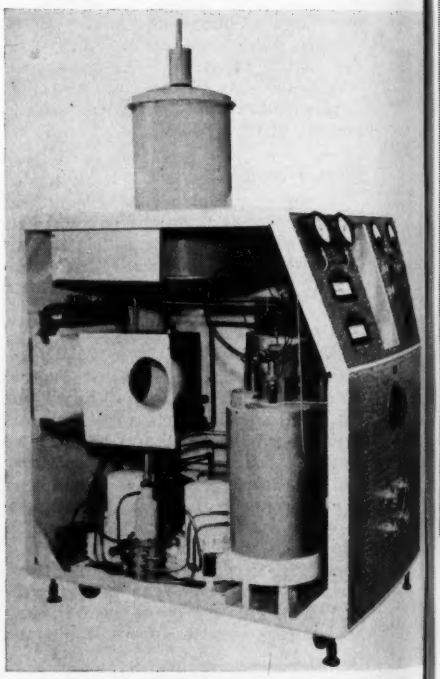
On leaving the pot the gas passes through a heat exchanger which reduces the temperature of the gas to room temperature or slightly below. Because of the danger of contamination by uranium oxide the heat exchanger is expendable. The "O" ring seals between the pot and the heat exchanger are water cooled.

From the heat exchanger the gas passes through a filter arrangement before being pumped back into the circuit for re-use. A small pulse-balancing reservoir and a by-pass circuit ensure a constant pressure.

On the safety side, all electrical connections are interlocked for water flow and temperature control. The equipment is tested for hydrogen leaks at the highest temperature range which each part of the circuit will be called on to maintain. The electrical circuits are to international coding and a full diagram to all circuits is provided with the plant. Remote links are provided for coupling to auxiliary equipment.

(Western Detail Manufacturers Ltd., Western Works, Staple Hill, Bristol.)

1103 for further information.

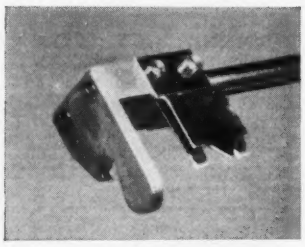


The mobile argon gas purifier by Western Detail Manufacturers. The side panel has been removed to show internal construction.

Opening Isotope Bottles

In spite of the wide range of remote attachments already available new handling problems are continually arising. Recently, for example, H.L. Instruments were asked to develop a special purpose head to facilitate removal of the foil and rubber bung from isotope bottles supplied by the Radiochemical Centre at Amersham.

The accompanying photograph shows the new opener which is interchangeable on any tong assembly produced to A.E.R.E. standard. The claw on the underside of the front plate is used to remove the aluminium foil whilst the two blades can grip and remove the rubber bung. For pipetting, the pointed top plate will remove the perforated centre of the cap.



Special purpose head for removing foil and rubber bung from isotope bottles.

(H.L. Instruments Ltd., 43 Poole Road, Westbourne, Bournemouth.)

1102 for further information.

Induced-Draught Cooling

Our recent notes on induced-draught cooling towers have prompted Film Cooling Towers to send us details of their packing for this method of water cooling. The Film Flow system distributes the liquid evenly over the packed area of the tower and gives the cooling unimpeded access to all parts of the packing.

The water is led to the tower either in a closed pipe or in an open culvert from which it is discharged into secondary troughs through orifices designed to prevent splashing. From the secondary troughs it is fed into weir-type spreader troughs running the entire length or breadth of the tower at a pitch of 6 in. The spreader troughs, which have specially shaped notches at 2-in or 4-in intervals, rest on the top layer of the tower filling. The filling comprises a number of horizontal trays of parallel laths, the direction of each layer of laths being at right angles to the trays above and below it. The effect in plan view is of a grid composed of 2-in square network. The water upon being discharged through the trough walls flows down the grid packing in an even film, changing direction through 90° in every 2 in down the whole depth of the stack.

This method of distribution ensures that the entire surface of the packing is evenly wetted, providing a very high heat exchange co-efficient, which, together with the fact that the cooling air has a relatively unimpeded flow throughout, effects an economy in the cost of the power to drive the fans. Also, by completely avoiding the formation of water drops, there is a smaller loss of water by entrainment: the use of baffle plates and drift eliminators is unnecessary.

The salient feature of the system, however, is the saving in space, as the packing depth can be reduced in some cases by as much as 50% of the space required by the normal drip-bar packing system. This is reflected in both lower capital costs and in considerable saving of the power required to obtain the pumping head.

(Film Cooling Towers (1925) Ltd., Brentford, Middlesex.)

1104 for further information

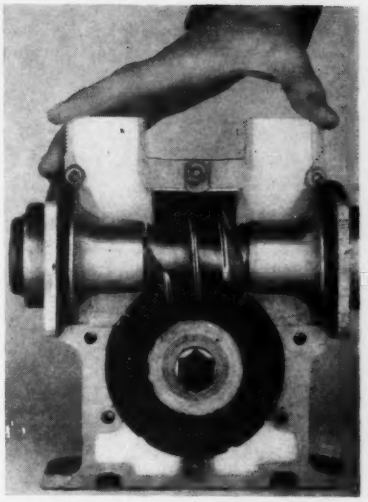
Vacuum Pump

A very compact vacuum pumping outfit designed for semi-automatic operation was recently supplied to Switzerland by Edwards High Vacuum. The unit comprised a Speedivac 1SC50 rotary air ballast pump displacing approximately 1.7 cfm backing an F203 fractionating oil diffusion pump capable of attaining an ultimate vacuum of 5×10^{-7} mm. Hg.

An electrically operated water-cooled baffle and isolation valve are mounted on the diffusion pump and a ½-in. magnetic valve and air admittance valve are mounted in the backing and by-pass lines. The pumping sequence is remotely controlled and the operator can set the pumps in motion and operate various valves merely by pressing buttons on the control panel.

(Edwards High Vacuum Ltd., Manor Royal, Crawley, Sussex.)

1105 for further information



A pump embodying the Archimedean screw lift principle is being marketed by Goodyear Pumps Ltd., of Camborne, Cornwall. The pumps, which give an exceptionally good performance under diverse conditions, are available in three sizes, 1¼ in., 1½ in. and 2½ in. suction and delivery connections, with outputs from 4½ to 167 g.p.m. against heads of from 53 ft. to 200 ft.

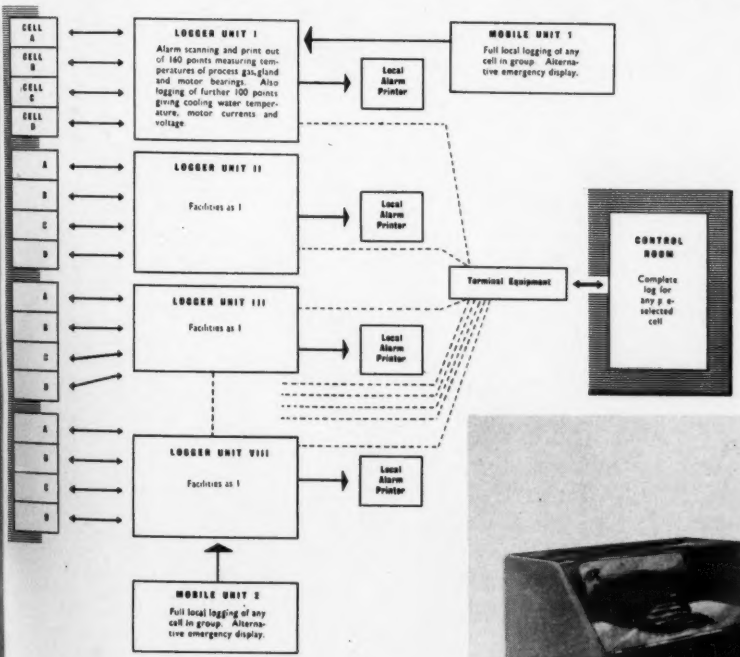
Data Handling at Capenhurst

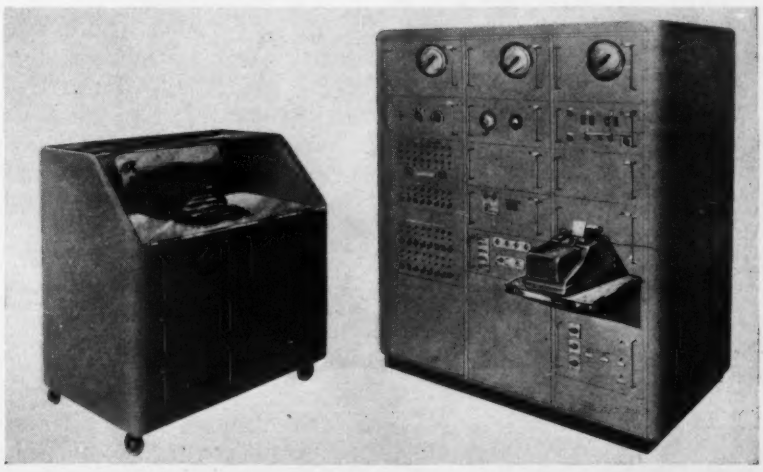
Immediate and accurate display of operating information is essential to the efficient control of any chemical process—particularly in nuclear engineering. To improve this particular aspect of the plant for gaseous diffusion of uranium hexafluoride at Capenhurst, the U.K.A.E.A. has ordered a data handling system which, as envisaged, will be the largest in Europe, both as regards value and number of points scanned. The contract has been placed with an A.E.I. company, Sunvic Controls. The system will comprise eight units, each capable of scanning 260 points and measuring process gas, gland and motor bearing temperatures, as well as cooling water temperatures, motor currents and voltage. Each unit will monitor signals from a group of four cells. A central control room will house equipment for printing, on demand, a tabulated log showing the value at all measuring points on any one of the 32 cells, the cell identification and the time of scanning.

In addition, two mobile print-out units are to be supplied. These will enable a complete log to be obtained at any time, for any cell, without interrupting normal scanning of the other three cells in the group.

(Sunvic Controls Ltd., 10 Essex Street, London, W.C.2.)

1106 for further information


CELL A
CELL B
CELL C
CELL D
LOGGER UNIT I
Alarm scanning and print out of 160 points measuring temperatures of process gas, gland and motor bearings. Also logging of further 100 points giving cooling water temperature, motor currents and voltage.
Local Alarm Printer
MOBILE UNIT 1
Full local logging of any cell in group. Alternative emergency display.
LOGGER UNIT II
Facilities as I
LOGGER UNIT III
Facilities as I
LOGGER UNIT VIII
Facilities as I
Terminal Equipment
CONTROL ROOM
Complete log for any 2 selected cells
MOBILE UNIT 2
Full local logging of any cell in group. Alternative emergency display.



(Above) Schematic diagram of the data handling equipment which Sunvic Controls are supplying to Capenhurst. (Right) Control cubicles of the Capenhurst units.

Patents Reviewed

These abstracts have been made from British Patent Specifications, complete copies of which can be obtained from the Patent Office, 25 Southampton Street, London, W.C.2, at 3s. 6d. each (including postage).

B.P. 784,321. Ceramic materials. W. J. Kramers, D. R. Whittaker, W. B. Rotsey. To: U.K. Atomic Energy Authority.

Normal ceramics lack ductility and, in order to obtain this, heterogeneous metal-ceramic (" cermet ") mixtures have been proposed. Continuous distribution of the metal phase is difficult to achieve, but it has been observed that metal-ceramic-distribution may be effected by the dissociation or splitting up of a chemical sub-compound or solid solution on cooling into metal and non-metal phases. A mixture of a refractory compound of a metal (thoria powder) and the metal (thorium metal powder) is heated to a high temperature in an inert atmosphere or in vacuo and then cooled. The proportions are so chosen that the product splits up into metal and non-metal phases (thoria powder 5.8 parts, thorium metal 19.8 parts).

B.P. 784,375. Glass to metal seal. To: Atomic Energy of Canada, Ltd. (U.S.A.).

Palladium metal is widely used in chemical apparatus because it permits selective and rapid diffusion of hydrogen through itself, particularly when heated. Hitherto it has not been possible to connect the thin-walled palladium tube usually employed directly to the remainder of the apparatus made of soft glass due to the large difference between the thermal expansion coefficients and, therefore, a short platinum tube was inserted between the palladium and the glass. It has now been discovered that palladium can directly be secured to glass by means of a solder glass of low fusion point.

B.P. 784,609. Process for reducing acidity of nitric acid solutions containing metal salts. T. V. Healy. To: U.K. Atomic Energy Authority.

In the processing of aqueous nitric acid solutions of chemical substances (fission products), wherein reduction of the bulk of the solutions is carried out by evaporation, the concentration of the nitric acid may become undesirably high. It has been found that in a solution in which the nitric acid concentration does not exceed 8 N the following reaction takes place with formaldehyde:—

$$3\ CH_2O + 4\ HNO_3 \rightarrow 4\ NO + 3\ CO_2 + 5\ H_2O,$$

and nitric oxide is capable of decomposing nitric acid of concentration above 8 N to produce nitrogen dioxide and water. Thus, the process of reducing the acidity is first carried out with a heated solution not exceeding 8 N which is treated with formaldehyde, yielding nitric oxide which is passed into contact with a further solution of acidity above 8 N to reduce this acidity.

B.P. 784,793. Lubricants resistant to atomic radiation. To: Esso Research and Engg. Co. (U.S.A.).

Conventional lubricants fail under conditions of high neutron and gamma radiation. Moderators, in order to reduce the damaging effect of gamma radiation, must decrease the energy content of the rays by providing a high frequency of collisions between gamma rays and electrons. The moderator must have a certain " gamma ray absorption coefficient " determined by molecular weight and density of the material. The new lubricant composition is a lubricating oil having incorporated therein a sufficient proportion of an element or compound (powdered heavy metals; minerals of a laminar structure) having a gamma ray absorption coefficient of at least 3 and a sufficient proportion of an element or compound (cadmium samarium gadolinium) having a capture cross-section for thermal neutrons of at least 2,500 barns.

B.P. 784,882. Uranium alloys. P. C. L. Pfeil. To: U.K. Atomic Energy Authority.

Alloys of high-tensile strength at temperatures up to 800°C and increased resistance to oxidation as compared with uranium metal are made of uranium, molybdenum (10 to 20%) and zirconium (5 to 10%). The uranium may be enriched in the isotope U233 or U235.

B.P. 784,890. Fuel elements for nuclear reactors. K. H. Dent. To: U.K. Atomic Energy Authority.

At present, the principal factor limiting the maximum safe operating temperature in vertical fuel elements is the creep strength of the canning material, so that any design which removes load has merit. The load in this design is carried by a member having a creep strength superior to that of the canning, and is fixed so as to carry the stresses due to the weight of the fuel element. The carrying member is preferably made of a material having a low neutron absorption (beryllium or zirconium alloy). In some cases this might not be the best solution and then the load carrier must have a small volume only (e.g., a pin screwed into the fuel element connected with an external support).

B.P. 785,050. Nuclear reactor heated boiler systems. R. V. Moore, W. R. Wootton. To: Babcock and Wilcox, Ltd., R. V. Moore.

When a heat transferring liquid is circulated through the reactor and then through the boiler in closed circuit it is desirable that the temperatures of the fluid on entering and leaving the reactor are controlled at predetermined figures or range of figures as the heat output of the reactor changes. Controlled by-passes for pressure fluid with their massive ducts, valve gear and expansion joints are cumbersome. A simpler form of control can be exercised by manipulating the mass flow of the heat transferring liquid to maintain the temperature at the outlet from the reactor at a predetermined figure or range of figures according to load and by controlling the pressure in the boiler to maintain the temperature at the inlet to the reactor at another predetermined figure or range of figures according to load. The cumbersome by-pass system is thus replaced by a simple pressure control valve on the boiler and a speed controller on the circulators for the heat transferring liquid. Where a multiple pressure boiler arrangement is used (high and low pressure boiler units in series or parallel relative to the reactor coolant flow) it is possible to achieve the required control by manipulating one boiler pressure only or first the lowest pressure and then the higher pressures in ascending order (in a double-pressure cycle for a turbo-electric generating plant, the high-pressure part is kept constant, the low-pressure part is adjusted). Automatic control of the mass flow and of the boiler pressure may be obtained by using thermostats for varying the speed of fluid circulators and the opening of the steam outlet valves.

B.P. 783,278. Titanium and zirconium alloys. To: Western Electric Co., Ltd. (U.S.A.).

The low neutron capture cross-section of zirconium has made this element, and certain of its alloys, of interest as a structural material in nuclear energy devices. Titanium and its alloys have the advantages of low density and high temperature corrosion resistance for lightweight structures (aircraft; jet engines). Zirconium and titanium exist in body-centred cubic (beta) state above about 860°C and in the close-packed hexagonal (alpha) state below about 860°C. Repeated transformation from one crystalline state to another results in structural weakening. This transformation on repeated exposure to temperatures cycling about the transformation point does not occur in certain alloys which, however, have not the ductility of pure titanium and zirconium. It has been found that titanium-osmium alloys, zirconium-osmium alloys and titanium-zirconium-osmium alloys possess the advantage of retaining the body-centred cubic (beta) structure even when cooled far below room temperature and their ductility and malleability are not substantially different from those of elemental titanium or zirconium. The alloys offer also an increase of many times in yield strength as compared to elemental titanium or zirconium (titanium and zirconium alloys generally show an increase in yield strength). The osmium content should not exceed 7 atom per cent. of the alloy and must not be below 4 atom per cent.

B.P. 785,344. Production of vanadium metal. J. S. Broadley, C. Tyzack. To: U.K. Atomic Energy Authority.

Refers to the hydrogen reduction of the trichloride of vanadium. In the course of this reduction a degree of disproportion of the tetra- and di-chlorides is inevitable and this represents a loss in reduction efficiency due to the escape of the very volatile tetrachloride of vanadium. This drawback can be overcome by a reduction in two stages, a first stage at a temperature in the range of 400 to 500°C (450°C) and a second stage at a temperature in excess of 950°C.

B.P. 785,505. Irradiated polyethylene and products therefrom. To: General Electric Co. (U.S.A.).

Polyethylene which has been treated with high energy electrons and, in certain applications, maintained at elevated temperatures (125 to 175°C) continuously for very long periods, has shown a degradation as evidenced by a pitted surface and excessive flow. Further, when irradiated polyethylene has remained in contact with copper (as insulation) for 25 to 50 hours at such or higher temperatures, a reaction appears to occur causing " greening " of the copper. A green film develops on the surface which reduces the adhesion of the polyethylene to the copper core. Incorporation of stabilizers has been insufficient. The interposition of a resinous coating (phenolic varnishes) protecting the copper has solved the problem.

B.P. 785,507. Radiochemical preparation of copolymers of maleic-anhydride and olefinic materials. To: Esso Research and Engg. Co. (U.S.A.).

The materials are exposed to a radiation of at least 10,000 R/h until polymerization is effected. Suitable types of radiation include gamma rays, X-rays, beta rays, alpha particles. High-intensity gamma radiation used include nuclear fission by-products, materials made radioactive by neutron radiation are preferred.